ELEMENTARY GENERAL SCIENCE

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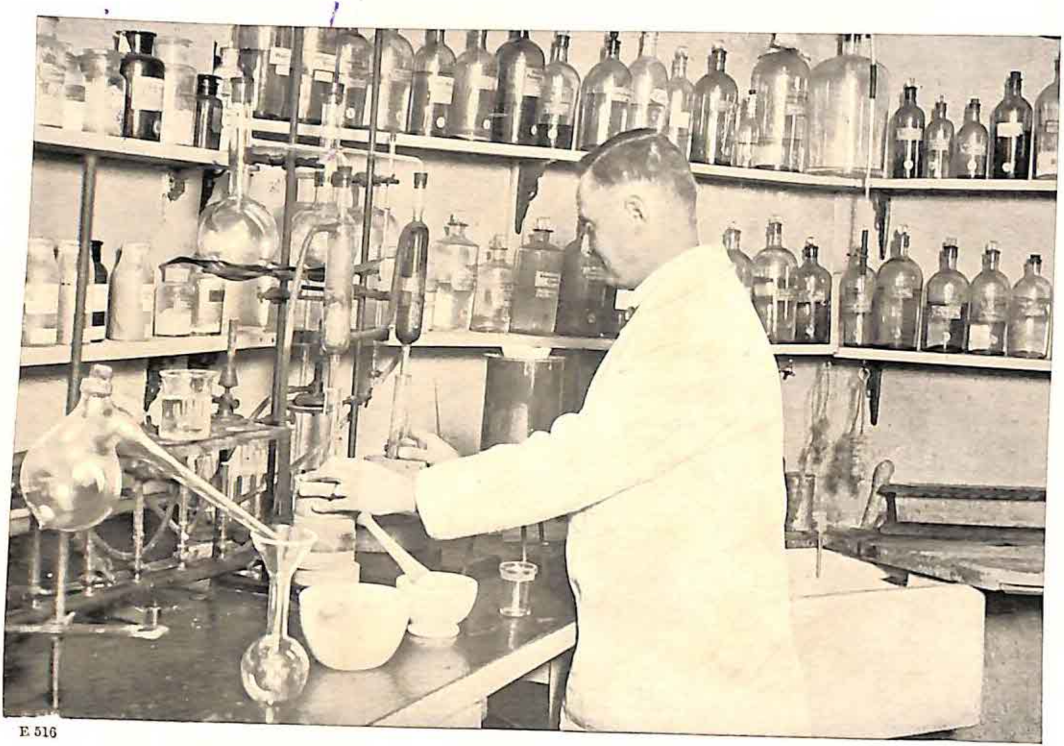

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Photo. Topical

A MODERN MAN OF SCIENCE

A chemist at work in his laboratory

ELEMENTARY GENERAL SCIENCE

A Course for Boys and Girls

BY

A. G. HUGHES, B.Sc., Ph.D., M.Ed.

AND

J. H. PANTON, M.A.

Book I

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Elementary General Science
A Course for Boys and Girls

BY
A. G. HUGHES, B.Sc., Ph.D., M.Ed.
AND
J. H. PANTON, M.A.

In Three Books

Elementary General Science
A Book for Teachers
By A. G. HUGHES, B.Sc., Ph.D., M.Ed.
Cloth boards

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PREFACE TO TEACHERS

This is the first of a series of three books designed to provide a course in Science for boys and girls of average ability between the ages of 11 and 15.

Much admirable advice on the teaching of Science has already been published, and though many general propositions may, in the abstract, command ready assent, considerable difficulty is being experienced in translating precept into practice.

We are exhorted, for example, to relate science in school to the events of everyday life. We are reminded that physics and chemistry are of supreme importance, but we are also urged to recognize the claims of biology, a branch of science which is obviously of vital importance in connexion with many serious problems of modern life. We are next reproached for neglecting such aspects of science as geology and astronomy which are full of interest for boys and girls. We are warned, however, that we must teach science, not sciences. But the more we try to adapt our science courses to these views, the more we are in danger of being justly criticized for scrappiness and incoherence.

One plan of obtaining some coherence among such a medley of material is the "topic method". Using this method, we group the numerous items round a small number of important everyday topics, such as, Heating our Homes; Washing our Clothes; Useful and Harmful Insects; The Soil of our Gardens; The Sun and Moon. This plan certainly reduces the incoherence of some old-time courses in which single lessons on such unrelated subjects as Convection, Soap, Flies, Chalk, followed one another with gay inconsequence. The coherence obtained by the "topic method" obviously depends on the extent to which the topics themselves can be related to one another. In some other subjects —in geography and history certainly—we have a unifying thread which runs through the whole course. We try to give children some more or less coherent idea of how mankind lives and has lived on this planet. There is really only one topic—The Process of Living. When studying geography we look through the spectacles of geographers at life in space; when studying history we look through the spectacles of historians at life in time. Our thesis is in conception a very simple one: it is that in studying science we should look at the same topic, The Process of Living, but through the spectacles of men of science. Our course will then consist of one main theme—Living—and everything we study will be related to it.

The subject is admittedly baffling in its complexity, and the very metaphor we have just used reminds us of a danger. Our pupils are growing children and not mature thinkers; we must therefore be careful to adjust the scientific spectacles to their growing needs and abilities. For that reason, we have made the course concentric and progressive, starting with a very simplified version of life.

There are four main and obvious activities which contribute to the process of living at every level. Even plants must partake of air and food, and in getting adequate supplies, they must move in response to environmental influences to which they are sensitive. These four activities—breathing, feeding, moving, and sensing—are more obviously developed in animals, and they are most easily appreciated by children as elements in their own lives. Human life is therefore always taken as the starting point. We begin by studying how we ourselves breathe and feed; how we move ourselves and other things about by the aid of our living machinery; and how the process of living is facilitated by the physical contact with our environment which we experience through the senses. From this starting point, we go on first to examine the same four vital activities in lower animals and in plants; second, to study how man has by scientific invention increased the effectiveness of these four vital activities in his own life. Thus we emphasize both the solidarity and the diversity of life; we recognize, on the one hand, our kinship with less developed forms, and, on the other hand, our kingly power over them; and running through the whole course there is necessarily a continuous study of the physical environment in which we live and move and have our being.

Breathing, Feeding, Moving, and Sensing—from a child's point of view, these activities are the greatest common measure of our complex topic; they appear as chapter headings in the course for each of the three years. This scheme at least has the merit that the subjects of the several chapters are intimately related; indeed, so numerous and inextricable are the connexions that only a few of them can be indicated in the text. The teacher and the pupils themselves will be able to supply and observe many other connexions and relations which, important though they are, we have been compelled to omit through considerations of space.

In addition to tackling the major problem of devising a comprehensive and coherent science course which shall be neither bewildering in the multiplicity of its topics nor unduly scrappy in their treatment, we have attempted to give help towards the solution of a minor problem, the making of notes. We have divided notes into two kinds—summaries and exercises. Concise and accurate summaries of knowledge are always difficult to write; for the notebook summaries, therefore, the " completion " method has been adopted throughout. The exercises should give scope for individual expression, but some guidance is necessary in the early stages, and in those exercises presenting special difficulties. The suggestions for notebook exercises are therefore intended to illustrate not only different kinds of suitable work, but also various methods of giving help to those who need it. They are in no sense intended to be exhaustive, and teachers will doubtless wish to set further exercises at their own discretion. It will be seen that although the pupils receive help in both kinds of notes, it is not necessary at any time to have resort to dictation or to mere transcription.

If the lists of missing words are covered up, the summaries, as printed in the text, will be found very useful when revising or testing the work which has been done.

It will be evident that the books are not an all-sufficient "self-educating" series. Individual work and private study are provided for, but so are demonstration lessons, oral instruction, and, perhaps most important of all, class discussion. For children, the best science textbook can never be more than a clever robot; the breath of life must be communicated by the teacher.

A. G. HUGHES.
ISLEWORTH J. H. PANTON.

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ELEMENTARY GENERAL SCIENCE

CHAPTER I

The Science of Living

One day a little boy, running about the kitchen, put his hand on the hot door of the gas-oven. Of course, it hurt! Surprised and annoyed, he cried out, " Why did it do that?" As he grew older, he grew more and more interested in the things and happenings around him, and his questions became more and more frequent.

" How do I go to sleep?"

" Why doesn't the ink run out when you hold up a fountain-pen?"

" Why does the sun go away at night?"

" How is cement made?"

" Why does steam lift the kettle lid?"

" Why has a tree got leaves?"

As time went on, he asked hundreds of such questions, and the more he learned the more interesting he found the world around him.

All through the ages, grown-up men and women as well as children have puzzled and wondered about the things in the world around them. And they are still doing it. Some men and women, very clever, patient thinkers, have found answers to many of the questions. These answers we call Science, and the men who find the answers to these difficult questions we call Men of Science. Some of these men have invented wonderful instruments and machines, which enable us to do many things our forefathers could not do. Every year new and more wonderful inventions are made, and every year men of science are finding new and better answers to puzzling questions. In this book we shall learn something of the work of great men of science.

A "How and Why" Book. You can begin at once to write down some of the How's and Why's which have puzzled you. Quite a good plan is to make a Class Question Book. You will have to be patient though, for it may not be possible to get answers to all your questions at once, and there are some questions which even men of science cannot yet answer.

If we are to study science successfully, we must have some plan to guide us. If you look at the questions in the first paragraph, you will see that they deal with subjects of all kinds—gas-ovens, trees, fountain-pens, steam, cement, the sun, and a boy—all mixed up together. If a man of science had to deal with a large number of mixed subjects, the first thing he would do would be to sort them out and put them into classes. He would try to find whether they were like or unlike one another in any way. If you examine the list you will see that some of the things are living, for example, the trees and the boy himself; and some are not living, for example, the gas-oven, fountain-pens, steam, cement, and the sun. Here then are two sorts or classes—living things and non-living things—and you see at once that everything can be put into one class or the other. Look around you out-of-doors, and wherever you may be—in a town or in the country, near a farm or on the seashore—you cannot help being struck by the endless number of different things there are. Among living things we notice plants and animals—tiny seedlings and giant trees, insects horses, birds and men. Among non-living things, we notice wood and stone, iron and water, and hosts of objects too numerous to mention. The great earth itself on which we walk, the sun, the moon and the stars—all belong to this great class of things which are different from us, different from plants and animals. We are alive; they are not alive.

You probably smile when you realize that you are in the same class as a cabbage or a worm. But if you decide to make a class of all living things, you and plants and animals have to be on the same list. There are, of course, very great differences among the various members of this large class. Animals can do many things which plants cannot do, and human beings are cleverer than the most intelligent dogs or monkeys. We are better thinkers than the other animals and we are cleverer at working with our hands. Even the best trained monkey cannot make a model, cut out a garment, or read the simplest story. We must remember too that in the non-living class there will be such widely differing objects as a toy cart and a motor-bus, a tennis ball and the moon. But although within each class there are enormous differences, the two classes are clearly separate from each other.

Men have invented many wonderful machines but they have never been able to manufacture a living thing. What is life? This is perhaps the most puzzling question ever asked. Men of science cannot yet answer it and perhaps they never will. But they have found out many interesting facts about living things, and they can teach us a great deal which will help us to live healthier and more useful lives. This is why we study science; it helps us to make our lives more interesting, more healthy, and more useful.

If you compare yourself with some non-living thing, a statue for example, you will see at once that you can do some very important things which the statue cannot do. Indeed, as long as you are alive, some of these things you must do. You must breathe and feed; you must move; and in the course of your daily life you cannot help seeing and hearing, tasting, smelling, and feeling. These are the special subjects we shall study, and you will find that our science lessons will lead us to ask many questions, not only about ourselves but also about other living things, and about the non-living things all around us.

We will begin by learning something of what men of science can teach us about breathing.

CHAPTER II

Breathing

Have you ever tried to hold your breath for any length of time while diving or while swimming under water? You find that however hard you try to stop yourself breathing, you simply cannot do so. It does not matter whether you are in water or out of it, whether you are sitting or standing, walking or running, asleep or awake, you must breathe in order to live.

All the time you have been alive you have been breathing. In and out, in and out! Day and night without stopping it goes on. How wonderful it is that we can keep on making all the movements necessary for breathing without getting tired, and indeed for most of the time, without even being aware that we are making them! How many times do you think you breathe in a minute?

Do the following experiments, working in pairs:

1. Sit down and count the number of breaths you take in a minute. Do this several times to see if the number is always the same.

2. Repeat the experiment while walking at an ordinary pace.

3. Run about until you are out of breath. Then count the number of breaths you take in a minute.

4. Find whether there are any differences, (*a*) between grown-ups and children; (*b*) between men and women, in their rates of breathing. (This experiment you can do best at home.)

Can you think of any other questions about rates of breathing which you could answer by doing experiments? Do not forget that you are not the only kind of living creature which breathes.

Notebook Exercise.—As you work through this book, you will find it is useful and interesting to make notes of some of the facts you discover. When you have sets of figures, it is often convenient to tabulate them like this:

Rates of Breathing

Living Creature	Number of Breaths per Minute
Myself (sitting down)	
Myself ("out of breath")	
Man (sitting down)	
Woman (sitting down)	
Baby (asleep)	
Baby (awake)	
Dog (asleep)	
Dog (awake)	

Class Scrapbook.—Another interesting thing to do is to make one large scrapbook for the whole class. You can perhaps elect an editor and assistant editors to look after it. But everyone can collect pictures and interesting paragraphs from newspapers and advertisement leaflets. Start now to make a collection about the subject of this chapter. Mount the cuttings on large sheets of brown paper and bind them in loose-leaf files.

You will find it more interesting if you arrange your material according to some plan. For example, the cuttings about breathing might be put into sections for (*a*) human beings, (*b*) animals, (*c*) birds, (*d*) fish, (*e*) plants. You will probably find it necessary to make other sections as you proceed.

Usually we pay little or no attention to breathing, but sometimes when we have been playing strenuous games or exerting ourselves in some vigorous exercise, we are painfully aware how difficult it is to obtain all the breath we need. On the other hand, hibernating animals such as the bear and hedgehog, which go into a kind of sleep during the winter months, scarcely breathe at all during that period. The general rule appears to be that the more a living thing moves about, the more quickly and deeply it breathes. Can you think of any other examples which show that this rule is true? It is important also to watch for examples which appear to break the rule.

The Ocean of Air in which we Live.

In order to live, then, we must keep on taking in something which the body requires; the harder we work or play the faster we must take it in. What is it that the body needs so much all the time? You have doubtless noticed that the space around us, though it seems to be empty, really contains something which you can often feel, although you are unable to see it. Has it ever struck you that, just as plaice and other fish live at the bottom of an ocean of water, we are living at the bottom of an ocean of air? The space all round us is full of air: it gets into every nook and cranny: it fills every jar and box as fast as we empty them of their contents. When violently disturbed, the air ocean is rough: we feel the airy waves dashing against us: we hear the noise they make and we see the commotion they cause. We feel the wind and we sometimes see the damage it does to buildings and trees. But when everything is calm, we get so used to pushing our way through the air, that we nearly always forget it exists. We talk of rooms and jars being "empty" when they are really full—full of invisible air. Here are two simple experiments which will help you to remember that an "empty" jar is really full.

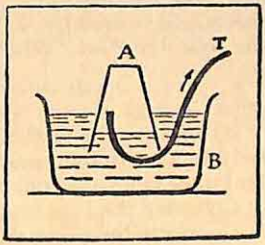


Fig. 1

5. Invert an "empty" glass tumbler A in a deep basin of water B. How far does the water rise in the glass? Why does it not come to the top of the glass however hard you press down?

Use a piece of rubber tubing T, and suck some of the air out of the tumbler. What happens?

6. What will happen if you turn the glass over on its side, keeping the mouth below the surface of the water? Try it.

Although we cannot see air, or taste it, or smell it, or catch hold of it, it is just as real as water or wood. We do not notice air so much, for we can move through it sc easily. Moving through water is much more difficult, and who would be so foolish as to try to walk through a tree! But even air does press against us, as we find out when we run very quickly. We shall learn more about the pressure of air in a later book. The weight pressing down on us, living as we do at the bottom of the air ocean, must be pretty great, for men of science know that air extends to a height of at least 45 miles above us, and some think that it may extend even as far as 500 miles up.

The Air we Breathe out.

When we breathe, we take into our bodies some of the air which is filling the space all around us, and after using it for a purpose which we will discover later, we get rid of it and take in a fresh supply. Is there any difference between the air taken in and that which is breathed out after we have finished with it? The following experiments will help you to answer the question:

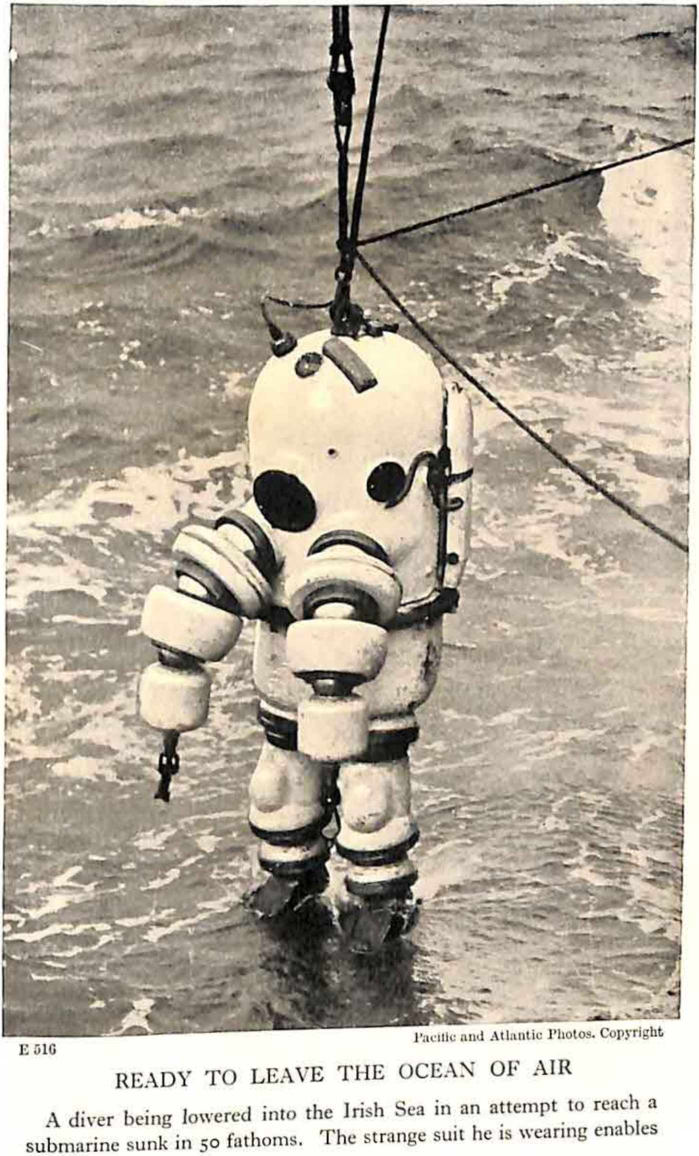
7. Fill a bottle with cold water to keep the glass cool. Dry the outside carefully, and then breathe for a few moments on the cold dry glass. What happens?

8. Into a small quantity of lime-water, breathe through a straw or a glass tube for a few moments.

By means of a football pump and a length of rubber tubing, bubble air through another sample of lime-water for the same length of time at about the same rate.

Compare the lime-water in the two experiments.

Continue bubbling air with the football pump for about ten minutes.



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READY TO LEAVE THE OCEAN OF AIR

A diver being lowered into the Irish Sea in an attempt to reach a submarine sunk in 50 fathoms. The strange suit he is wearing enables him to breathe under water.

Facing p. 8

9. Fit up apparatus as in fig. 2. The jars contain lime-water. The T tube is connected with the tubes B and C by rubber tubing. (If there is difficulty in getting a glass T tube, a metal one can be bought at a plumber's.) Breathe in and out gently through T. Notice carefully what happens in each jar.

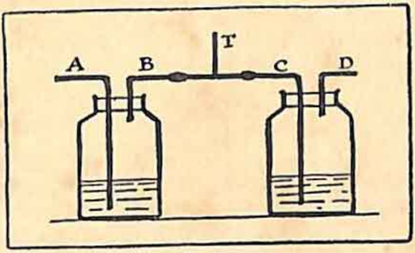

Fig. 2

During the time air is in our bodies, it is changed in three ways. (i) You know that the air we breathe out is warmer than the air we breathe in. (ii) Experiment 7 showed that when this air is cooled again, drops of water are formed. This is because it really contains water—not liquid water, but water in the form of an invisible gas which we call water vapour. During the time air is in our bodies, the amount of water vapour in it is increased. (iii) The third change is more mysterious. The air we breathe out turns lime-water cloudy very much more quickly than fresh air does. Men of science tell us that there is only one kind of gas which will turn lime-water cloudy; its name is carbon dioxide or carbonic acid gas. We therefore learn from experiments 8 and 9 that the amount of carbon dioxide in air is increased during the time the air is in our bodies.

Carbon Dioxide: a very useful Gas.

You may be interested to know that while fresh air contains about 0·03 per cent of carbon dioxide, the air we breathe out contains 3·5 per cent, that is, nearly 120 times as much. Carbon dioxide is so common in the world that you ought to know more about it. The following is a convenient way of making this gas in larger quantities:

10. Look at fig. 4, p. 12. Put some marble chips into the flask B. On to the marble pour some dilute hydrochloric acid through the funnel A.

(*a*) Bubble the gas through lime-water by means of the delivery tube C. What does the result show?

(*b*) Collect some of the gas in the way suggested in the diagram. Test whether the jar does really contain any carbon dioxide.

Do you think carbon dioxide is heavier or lighter than air?

(*c*) Plunge a lighted match or a burning piece of paper into a jar of the gas.

You may be wondering why this gas is called carbon dioxide. The following experiment will explain the first half of the name; you will learn the meaning of "dioxide" in Book II.

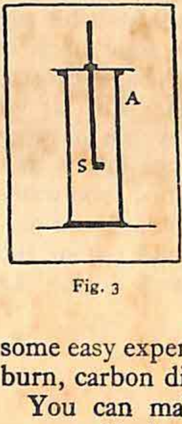

Fig. 3

11. Take some powdered charcoal (chemists call it carbon), and burn it in a deep jar. This can be done by heating it in a deflagrating spoon S over the bunsen burner and then plunging it into the jar A. Test the gas in the jar by putting in a glass rod which has been dipped in lime-water.

A great many substances contain carbon, and when they burn, the carbon in them is made into carbon dioxide. Coal, candles, wood, paper, sugar are good examples, and you can now invent some easy experiments to show that when these substances burn, carbon dioxide is really formed.

You can make carbon dioxide at home by pouring some acid, for example, vinegar or lemon juice, on to some baking soda, or washing soda. (Use small quantities.)

12. Pour some water on to some baking powder in a test-tube. What happens? (Baking powder is a mixture of tartaric acid and baking soda.)

13. Heat some baking soda gently in a test-tube and find whether carbon dioxide is given off.

It is the same gas, carbon dioxide, which bubbles out when you open a bottle of mineral water. You can see a simple apparatus in some shops for forcing the gas into ordinary drinks to make them " fizzy ". It is carbon dioxide again which causes the " fizziness " when seidlitz powders or kali are mixed with water.

Our experiments have shown that breathing increases the amount of carbon dioxide already in the air. When we remember that for thousands and thousands of years many millions of people and other living creatures have been breathing, it appears at first sight that there may come a time when we shall no longer be able to light our fires. You will be relieved to know at once that this is not likely to happen. As we shall learn in the next chapter, the carbon dioxide, which is being continually manufactured by the breathing of living animals, is being used up for a very important purpose. In the long run, therefore, the amount of carbon dioxide in the air is not really increasing. It remains very steady at the low figure of about 0·03 per cent.

Discussion Questions.—A good way of getting answers to questions is by discussing them in class. Each member should say what he thinks, and at the end your teacher will no doubt " sum up ". Your " How and Why Book " will provide you with some questions for discussion. You will find others suggested in this book. Here are four to start with:

(*a*) Why is baking powder or soda used in making cakes? Test whether your explanation is the right one by making two small cakes, one with baking powder, the other without.

(*b*) When baking powder is used in cake making, it is put in last, and the mixture is then put into the oven immediately. Why?

(*c*) Some cake mixtures do not contain baking powder or soda, but the cookery books say, " Beat well ". Why?

(*d*) Some fire extinguishers contain a strong solution of soda and a bottle of acid. In case of fire, you are told to strike a knob provided on the outside. What happens?

Notebook Summary.—Complete the following paragraphs, filling in the right words in the gaps. All the necessary words are given in the list printed in brackets. Use all these words and no others. Notice that the list is arranged in alphabetical order to help you to find quickly whether the word you think you want is there.

B. 1. BREATHING

(air; breathe; carbon; carbon dioxide; colourless; dilute; extinguished; gas; heavier; increased; lime-water; marble; not; three; vapour; warmed.)

During the time -1- is in our bodies, it is changed in at least -2- ways, viz.,

(*a*) It is -3-.

(*b*) The amount of water -4- in it is -5-.

(*c*) The amount of -6- in it is increased.

Carbon dioxide is the -7- which is made when -8- burns. It can also be made by pouring -9- hydrochloric acid on to some chips of -10-. We ourselves are also continually making carbon dioxide by using inside our bodies the air we -11-.

Carbon dioxide is a -12- odourless gas, and is -13- than air. The gas itself will -14- burn, and if burning things are put in it, the flames are -15-. It is the only known gas which will turn -16- cloudy.

Notebook Exercise.—Describe experiment 10.

(The following notes will help you. In this kind of work you should use as few words as possible. Notice how a diagram helps you to do this. Always give the date on which you did the experiment you describe; and give the page in your text-book where you can read more about it.)

ONE METHOD OF MAKING CARBON DIOXIDE

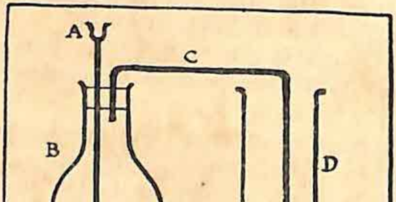

Fig. 4

(Book I, page 10)

(carbon dioxide; chips; collected; delivery; dilute; flask; funnel; hydrochloric; jar; marble.)

We made some -1- by pouring a little -2- -3-acid through the -4- A on to some -5- -6- in the -7- B. By means of the -8- tube C we -9- the gas in the -10- D.

Noses and no Noses.

So far, we have considered only the breathing of human beings and such animals as cats and dogs, bears and hedgehogs. All these creatures are large enough for us to see, by their movements, that they do really breathe. More than that, they have nostrils which are obviously used for taking in breath. If we could look inside, we should find that even the straightest nose contains a very crooked passage. The walls of this passage, as you know, are always moist and warm, and they are lined with very tiny hairs. Tiny specks of dust, and even microbes which are smaller than specks, are stopped by the hairy walls of this wonderful filter, and by the time the air has passed right through the crooked corridor inside your nose it is clean, warm, and slightly moist, as it ought to be before it gets inside your body. You can now begin to understand why you ought to breathe through your nose and why it is important to keep your mouth shut except when you are eating, drinking, singing, or talking. When, in a later book, you learn more about the dangers of microbes, you will be even more certain what an important rule of health this is: Always breathe in through your nose.

Some living creatures breathe through openings which appear to us to be curiously situated. Most kinds of birds, for example, breathe through openings near the base of their beaks, though the kiwi has openings in the tip of its beak; spiders breathe through slits in the under surface of their abdomens; caterpillars have openings in their bodies. Even the tiniest insect must breathe as long as it is alive, and it must have some kind of opening through which fresh air can be taken in.

Do Underground Creatures Breathe?

If we leave our ocean of air and go down into the ground we still find living creatures. Do they breathe? Yes, the general rule is still the same; if a creature is alive it must breathe, and creatures which live underground find the air they need in the earth. Worms (they breathe through their skin) need a good deal of air and they therefore live near the surface of the earth. Deeper down, air is scarcer and only special kinds of creatures, which need very little air, can live there. Very deep down, there is no air, and therefore no living creature.

Do Water-dwellers Breathe?

There is still another place where we find living creatures—in water. Do fish breathe? Here are some things for you to do in order to find an answer to this question:

14. Watch the mouth of a fish in the aquarium. Look carefully behind the eye of the fish. You will notice flaps (gill-covers) opening and closing on each side of its head. Have these movements any connexion with the movements of the mouth?

15. Examine the gills of a dead herring or codfish, particularly the part underneath the gill-cover.

16. Take a fairly large fish from the aquarium and place it for a short time in a glass bowl of water to which a small quantity of lime-water has been added. (Do not keep the fish in the dilute lime-water for a moment longer than is necessary for this experiment.)

You will have noticed that fish make regular movements of the mouth and gills—just as regular as the movements you make when you are breathing. Fish look as if they are " breathing " water. But experiment 16 showed us that a fish makes carbon dioxide just as we do when we breathe air. Is there any air in water for fish to breathe?

17. Fill a glass with water from the tap and allow it to stand for a few minutes. Observe the inside of the glass carefully.

18. Heat a flask of tap water. Observe whether any bubbles of gas are given off *before* the water boils.

These experiments show you that water does contain gas. As a matter of fact, the bubbles you saw consist of the same gases as the air around us. We see, therefore, that although fish live in water, they are not altogether cut off from all supplies of air. It is possible by boiling water to drive out practically all the air it contains. Have you ever tried to drink water which has been boiled and then left to get cold? We say it tastes " flat ". That is because it is practically airless. It has been found that if fish are put into such airless water, they die in a very short time. We may then be reasonably certain that although fish live in water, they do need air to breathe just as all other living creatures do. How do they manage to extract the air from the water?

Your examination of a herring will have revealed, underneath the gill covers, the gills themselves—red comb-like frills attached to bony pieces near the throat of the fish. When breathing, the fish takes in water through the mouth and sends it out at the side of its throat; this water passes over the gills which are able to take from the water that part of the air which the fish requires. Carbon dioxide is made inside the fish. But the fish has no use for most of this gas, and it is discharged into the water by the gills.

You can now understand why we change the water in aquaria. In large tanks you will sometimes see a length of pipe from which air is bubbling into the water. This plan ensures a constant supply of fresh air in place of the air which the fish are using up, and so serves the same purpose as changing the water.

We cannot, with our breathing apparatus, use the air which is in water. Naked men who dive for pearls and sponges cannot stop under water for more than about three minutes. Some inhabitants of the sea are like us; they must breathe the air of the atmosphere. A whale, for example, is obliged to come to the surface occasionally to breathe out the air which has been used in his body, and to take in a fresh supply.

Frogs are interesting, too, for although they breathe through nostrils, they are also able to take in air through their smooth damp skin. It is believed that we ourselves are able to take in a little air through our skin, but we do not use this method of breathing so much as frogs do. Fresh air baths are, however, good for health.

Do Plants and Trees Breathe?

We have learnt that all creatures which inhabit the earth must breathe as long as they are alive, no matter where they dwell. But animals, worms, and fish are not the only living things upon the earth. Trees and plants, grasses and weeds are to be seen growing almost everywhere. Must they breathe too?

The following experiments will help you to answer this question:

19. Place some damp sawdust in the bottoms of two jars. Into one of them place a small handful of peas or beans, and leave for a few days. Then tie up the mouths of the jars with strong paper and leave over-night. Next day test the gas inside the jars with a rod dipped in lime-water.

Examine the peas or beans and note any changes in them. Are they alive?

20. Shut up in a cupboard over-night a fairly large plant growing in a pot (an aspidistra is suitable); place a saucer of lime-water beside it, and another saucer of lime-water outside the cupboard. Examine the two specimens of lime-water early next day and compare them. What does the result show?

While waiting for the results of these experiments you can bring your notebook up to date.

Notebook Summaries.—Complete the following paragraphs:

B. 2. ALWAYS BREATHE IN THROUGH YOUR NOSE

(certain; filter; healthy; moist; nose; obey; obstructions; warm.)

This is a very important rule which we must -1- if we want to be -2-. If we breathe in through the nose, we can be practically -3- that the air which goes into our bodies is -4-, -5- and clean. We see then that the -6- is a very wonderful and valuable -7-. We should always be careful to keep it free from -8-.

B. 3. Air is Necessary for all Living Creatures

(air; alive; atmosphere; earth's; gills; land-dwellers; living; miles; must; require; under; water.)

All -1- creatures which inhabit the earth -2- breathe. This is true whether the creatures live in the atmosphere, or -3- the ground, or even in -4-. We know, therefore, that wherever any creature is -5-, a supply of -6- must be present. We live at the bottom of the -7-, a great ocean of air at least 45 -8- deep. Air is also found in soil, and in small quantities, in the water which we find on the -9- surface.

Most creatures which live in water have a different kind of breathing apparatus from that which -10- possess. They are able, by means of -11-, to take out of the water that part of the air which they -12-.

Notebook Exercise.—By completing the following sentences describe experiment 16.

An Experiment to find whether Fish make Carbon Dioxide (Book I, page 14)

We put a live fish into . . . . . . At the end of a few minutes, ... , showing that . . . .

Experiments 19 and 20 have shown that sprouting seeds and growing plants give off carbon dioxide. Exactly the same process is going on in living plants as in living animals. Plants, like animals, take in air: they use it for a particular purpose and in so doing they increase the amount of carbon dioxide in it. Then, like us, they get rid of it. It is easy to believe that animals and fish breathe, because we can see the regular in-and-out movements they make. With plants it is different, and however carefully you observe them you cannot see any breathing going on. How then do plants manage to breathe? Fig. 5 shows you a

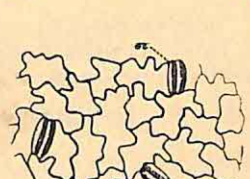

Fig. 5

much magnified view of the skin on the under-side of a leaf. This reveals the fact that leaves are provided with tiny breathing holes. These holes (men of science call them stomata) are found on many parts of plants above ground, but they are most plentiful on the under-sides of leaves. Each of these openings in a leaf leads to a space, and the air passes through each tiny passage and fills up all the spaces. We have already noted that the air fills every nook and cranny; it is interesting to learn that this is true of the tiniest spaces, and that air passes through holes which are far too small for the eye to see without help.

If you have a microscope, it is interesting to prepare slides of the skins of various leaves and to examine them. Make sketches of their appearance in your notebook.

Notebook Summary.—Complete the following paragraph:

B. 4. AIR IS NECESSARY FOR ALL LIVING PLANTS

(air; breathe; carbon dioxide; holes; living; stomata.)

All -1- plants which inhabit the earth must -2-. They do so by taking in -3- through countless tiny breathing -4-, which are called -5-. The air which plants give out through these holes contains an increased amount of -6-.

Notebook Exercises.—(*a*) Describe experiment 19.

This can most easily be done by drawing diagrams and writing about them. Like this:

AN EXPERIMENT WITH SPROUTING SEEDS
(Book I, page 16)

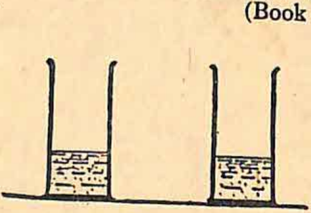

Fig. 6a

Jars A and B contain.. .. ..

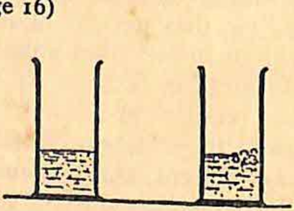

Fig. 6b

We put a handful of.. .. ..into B.
At the end of....days the.. .. .. ..
started .. .. ..

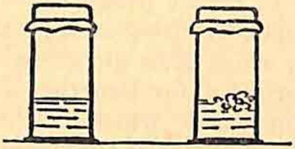

Fig. 6c

We......the mouths........and left the jars for......hours

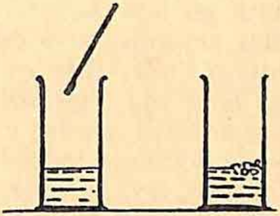

Fig. 6d

By means of a drop of lime-water on the end of a glass rod, we found that the amount........

We know therefore that the sprouting seeds made ....

(*b*) Add as many examples as you can to the following:

Living things	*Openings for breathing*
Human beings	Nostrils
Plants	Stomata

(*c*) The earth's diameter is about 8000 miles. The deepest part of the ocean is about 7 miles. Make the necessary calculations to enable you to draw to scale in the playground a diagram showing where air can be found in, on, and around the earth. Notice what a very narrow belt of space can be inhabited by living things.

The Importance of Clean Air.

You have still much to learn about breathing and about the air we breathe. But you can now begin to see how important it is to have a good supply of clean air, not only for human beings but also for every living thing, from the smallest plant and insect to the largest animal and tree. We can do much to prevent dirt from entering our bodies by breathing through the filters with which Nature has provided us, but it is, of course, impossible to stop some air from entering through our mouths. Plants are even more defenceless than we are, and one of the reasons why gardens do not flourish in factory towns is because the stomata of the leaves get choked up with dust and soot. We see therefore that we should do all we can to reduce the amount of dust and smoke which get into the air. Men of science are continually doing experiments to discover the best ways of making dustless roads; they are trying to invent better smokeless fuels and improved non-smoking fire-grates; they have invented cleaning machines which draw dirt straight into a container instead of stirring it up into the air. You may say, however, that the smoke which belches forth from factory chimneys is a result of the invention of machinery, and that the dustiness of roads has been caused by the invention of fast motor vehicles. Whether science has increased or decreased the cleanliness of the air is a subject on which you may hold different opinions. But the important fact for us all to remember is that a supply of clean air to breathe is a necessity for all living things. This being so, we see how extremely important it is to keep as clean as possible the great ocean of air in which we live.

Discussions.—(*a*) Have men of science increased or decreased the amount of dust and smoke in the air?

(*b*) How can we all help to keep the air clean?

Notebook Exercise.—Add as many examples as you can to the following list:

Ways of keeping the Air clean

(*a*) Use smokeless fuel.
(*b*) Make dustless roads.

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CHAPTER III

Feeding

In Chapter II we learned that all living things, plants and animals, insects and fish, are always breathing. Day and night, so long as they are alive, they never stop. But, as you well know, air alone will not keep us alive. Nor are the movements we make when breathing, the only kind of movements we are always making. Try the following experiments:

21. Place the forefinger of your left hand on your right wrist on the spot marked × in fig. 7. (You feel the gentle but regular beating of what is called your "pulse".) Count the number of beats in a minute. Compare this number with the number of breaths you take in a minute.

Repeat the experiment with your left wrist.

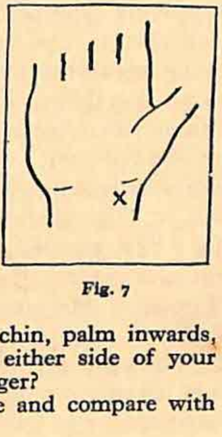

Fig. 7

22. Place your open hand under your chin, palm inwards, so that the thumb and forefinger lie on either side of your throat. What do you feel with your forefinger?

Count the number of beats in a minute and compare with the wrist pulse.

23. Try the same experiments after a short quick run.

These experiments show you that, in addition to breathing movements, you are also making regular movements of another kind. These movements, too, never stop. You may like to check the truth of this

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statement by feeling the pulse of someone who is soundly asleep.

Your pulse movements probably remind you of the throbbing of a motor engine. As a matter of fact, our bodies are in some ways very like engines and machinery. Machines are made to move, to do some work. The motor-car runs along the road, the loom weaves cloth, the steam navvy digs trenches, and the crane lifts weights. You can do all these things—run, weave, dig, and lift. And all the time the regular pump, pump of your engine is going on.

How do engines get the energy which enables them to move machinery? You think at once of petrol and coal. We shall learn that it is by the burning of these and other fuels that energy is obtained for running machines. Just as engines need fuel to keep machinery going, so do you. That is one reason why you take food; you are supplying yourself with fuel to keep yourself going. But that is not nearly the whole story. You and all living creatures may be like engines and machinery in some ways, but in other ways you are very different. When you were a year old you weighed twenty pounds or thereabouts; now you probably weigh about four times as much. What engine could by itself increase its weight like that? Consider some other living things. In a few months, the tiny nasturtium seed you put in the soil grows into a tall plant with scores of leaves and dozens of flowers. In three weeks, a tiny speck in an egg grows into a fluffy little chicken, and in a few months this chicken grows into a hen which is almost the same size as the mother hen which laid the egg. Food is necessary, not only to keep us going, but also to keep us growing.

We are different from engines in yet another way. When a piston ring, a sparking plug, or some other part of a motor engine wears out, the engine has to be repaired by putting in a new "spare part". Although, like the engine, we wear away slightly as a result of our activity, we do not need "spare parts", for we are continually renewing all our parts. All of us, even grown-ups who have stopped getting bigger, need food to keep us in repair.

Notebook Summary.—Complete the following paragraph (the initial letters of the missing words are given):

F. 1. FEEDING

Food is n—— to keep us g——, to keep us gr——, and to keep us in r——.

Notebook Exercise.—Make a careful record of what you eat and drink during a school week. You will find it convenient to make a table like this:

Day	Breakfast	Dinner	Tea	Supper	Between Meals
Mon.	Milk Egg Butter Sugar Salt Bread				
Tues.					

Class Scrapbook.—Start making a collection of cuttings on the subject of this chapter.

Six Kinds of Foodstuffs.

The many things you eat and drink can be arranged in quite a small number of groups. First, there is that most important of all drinks, water. Then there are foods which are fatty, foods which are lean, and foods which are sweet. Add to these, things like salt, and you have almost a complete scientific list of the different kinds of foodstuffs. Twenty years ago, it would have been called a complete list, but quite recently men of science have discovered that food contains minute quantities of very important substances, to which they have given the name of "vitamins".

There are a few other facts to be learnt before we can write down in the scientific way our complete list of foodstuffs. What we call lean is mostly muscle; it consists chiefly of substances which are called proteins. The sweet things we enjoy so much contain sugar. Men of science use the same word, and they have discovered several kinds of sugar. But here is a surprising fact. We do not eat all the sugar our bodies use; some of it is manufactured inside our bodies out of the starch we eat. Now we can write down:

A Scientific List of Foodstuffs

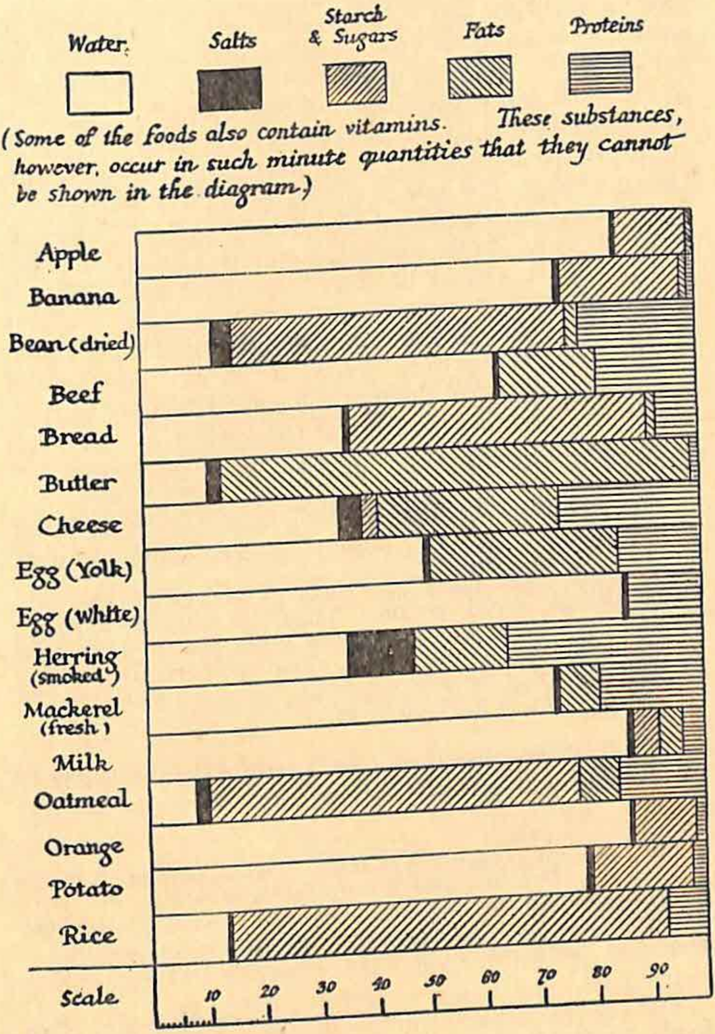
A. Water
B. Salts
C. Starch and sugars
D. Fats
E. Proteins
F. Vitamins

Nothing that you eat or drink is wholly made up of any one of these foodstuffs. Drinking water contains small quantities of salts; butter contains salt and water as well as fat; potatoes contain water, starch, proteins and salts. Fig. 8 gives an idea of the composition of some of the common things we eat.

You see that some eatables are mostly water; some are mostly starch; others are mostly fat; some are rich in protein, but none contains large quantities of salts. The amounts of vitamins are so tiny that they cannot be shown in the figure. What is the use of each of the six different kinds of foodstuffs? We will study each one separately.

Water: the best Thirst Quencher.

We could not live without water. For the inhabitants of a town, the water-works provide daily about 25 gallons per head for all home purposes. Of this supply, it is estimated that about 2 gallons per head are used each



(Some of the foods also contain vitamins. These substances, however, occur in such minute quantities that they cannot be shown in the diagram.)

Fig. 8

day for drinking and cooking. Water is also present in small or large quantities in practically everything we eat or drink. For example, three-quarters of the weight of a cooked egg is the weight of water which it contains; so is two-fifths of the weight of a loaf of bread. As much as four-fifths of the weight of your own body is water. On an average, you lose about six pounds of water every day through the action of the skin, lungs, and kidneys.

A supply of fresh running water is essential for life and health; it cannot be stored up as fat can. This is the reason why a man can go for forty days without eating food, though he would die of thirst in a much shorter time if he were denied drink as well as solid food. When you feel thirsty, it is a good thing to quench your thirst by drinking plenty of clean water, for although many solid foods contain some water, you cannot get enough by eating only.

The following experiment will help you to find out roughly how much water there is in some common foods.

24. Weigh some fairly thin slices of various eatables, e.g. apple, banana, bread, potato. Then put them in a warm, dry, airy place. Weigh them again every two or three days, and make a graph of the results. Find the percentage weight of water in each of the different foods and compare your results with those given in fig. 8 on p. 25.

The foods in experiment 24 " dry up "; the water in them turns into water vapour and disappears from sight into the air.

25. Take equal quantities of water in some saucers all of the same size. Place one near a warm radiator or fire, one on a draughty window-sill, one in a cool part of the room away from draughts. Look at them from time to time during the day to find from which saucer the water disappears most quickly.

Food manufacturers sometimes dry out the water from foods to make them lighter and more convenient for transport and storage. Before we eat such dried foods, we often put the water back by soaking them.

26. Weigh small quantities of some dried foods, e.g. prunes, haricot beans. Soak them overnight; dry them with a cloth, and weigh again next morning. Find the percentage increase in weight.

An important food for farm animals is hay which is, of course, grass from which the water has been dried out.

Milk is an important food from which water is often dried out. It is then sold either as condensed milk or in the form of powder. Many of the foods sold by grocers are dry; in fact, an old-fashioned name for groceries is "dry goods".

A very rapid way of changing water into vapour is by boiling it.

27. Heat some water in a flask and watch it carefully. Notice first of all the small bubbles which come out (see experiment 18, p. 14). Later, the water begins to boil.

Notebook Exercise.—Describe fully what happens in experiment 27, and see that your description contains answers to the following questions:

(i) What are the bubbles in boiling water?

(ii) Are they lighter or heavier than water?

(iii) What happens to them when they reach the surface of the water?

(iv) What happens to the vapour when it gets away from the hot flask? Why?

(v) What happens to the steam when it gets right away into the air?

When water boils, it is changing rapidly into water vapour and we can see bubbles of vapour rising quickly through the water, causing it to move violently. But we must not forget that water, which is not boiling, is very often being changed into vapour quietly from its surface. We say then that the water is evaporating. This word simply means "going away as vapour". On sunny days and even on cool days if the wind is blowing, you have probably noticed how puddles of water have disappeared from the asphalt playground; they have evaporated.

What tremendous quantities of water must evaporate every day from the surfaces of lakes and rivers, and most of all from the thousands of square miles of ocean surface on this earth! As you learn in geography lessons, sooner or later it all falls again as rain, or snow, or hail. And so the round of change for ever goes on, no drop of water ever being really lost—water to vapour and back to water, vapour again and back to water again. In Book II you will learn more of the interesting story of the water which is such an important part of our daily food.

Health-giving Salts of the Earth.

If you study your list of daily foods you will find that most of what you eat comes from plants and animals. Where else could solid food come from? There is the earth the animals walk on and in which the plants grow, but you quite rightly try to avoid eating earth. Since, however, plants get some of their food from the soil, and animals eat plants, you will not be surprised to learn that vegetables, fruit and meat do contain some of the very substances which form the soil. These substances are called salts, and men of science tell us that some of them are very necessary for helping to make bones, teeth and blood. Table or common salt is only one kind, but it is very important; it has been estimated that London consumes daily about 11 tons of this food. Chemists know hundreds of different kinds of salts; limestone, for example, is called a salt.

Why is the sea salty? The answer to this question reminds you that salts come from the earth. You see then that salts are continually being taken out of the soil by the rivers which wash them out, and by the plants which feed on them. But you cannot see the salts in sea water, although you can taste them. This is because they are broken up into such tiny pieces, that you cannot see them even with the aid of a microscope. It is not difficult, however, to get the salts back again from sea water. All you have to do is to get rid of the water by boiling or by evaporation and the salts will be left behind.

28. Get the salts out of some clear sea-water, or out of some salt water. (Use a porcelain dish, called an evaporating dish.)

If we shake up a powdered substance with a liquid, and the powder disappears, leaving the liquid perfectly clear, we say the substance has dissolved. The liquid with the dissolved substance is called a solution.

29. Using cold water, try to make solutions of some of the following salts: table salt; washing soda; blackboard chalk; alum; copper sulphate; potassium permanganate; marble.

(Use very small quantities of each salt in a test tube. If you want to dissolve a substance quickly in cold water, powder it and shake well.)

Salts which will dissolve in water are said to be soluble in water; salts which will not dissolve are called insoluble. Make lists in your notebooks like this:

Soluble in water	*Insoluble in water*
Table salt	Marble
—	—
—	—

When an insoluble substance is powdered, and shaken up with water, the pieces are still large enough to be seen by the naked eye. If the mixture is left to stand, the solid pieces will settle at the bottom, forming what is called a sediment. The clear water can then be poured away. A quicker way of separating the liquid from the insoluble solid is by filtering. A rough and ready filter often used in the kitchen is the gravy strainer; a better filter is the hair sieve; a still more effective filter is often made by stretching a piece of cloth, e.g. butter muslin, over a basin. The jelly bag used by cooks is another example of a filter. The pores in cloth are not very small, however, and some solid particles may be pressed through by the weight of the pulp. In making jelly, this unwanted solid is skimmed off during the final boiling so that the jelly when made is perfectly clear. A very effective filter can be made like this:

30. Fold a circular filter paper in half: then fold it again so that it is now a quarter of a circle. Open it, so that it forms a cone. Fit this paper cone in a funnel.

Prepare two filters in the way described above. Into one pour some solution of copper sulphate; into the other pour a mixture of water and powdered blue chalk. Compare the liquids which come through.

You see that by filtering you can separate solid sediment from a liquid but you cannot keep back any solid which is dissolved in the liquid.

It is most important that water should be carefully filtered at the water-works. The filters used are large tanks about 12 ft. deep, and sometimes they are as large as one acre in area. On the bottom is a layer of lumps of brick; on that is a layer of coarse shingle, then one of fine gravel, and on top a layer of sand—a total of about 2 to 4 ft. of filtering material. You can make a model of one of these filters in a flower-pot. Try how well it works by filtering some muddy water. (You should not drink the water filtered in this way even though it looks clear.)

We have learnt that if we want to dissolve a substance quickly, we should powder it, and then shake it up well with the liquid. There is a third thing we can do to make soluble substances dissolve quickly:

31. Shake up a little powdered alum with some water in a test-tube. When it has dissolved, put some more alum in and shake again. Keep on adding alum until you have a sediment which will not dissolve even after shaking well. The solution is now called a saturated solution. Warm the liquid and watch what happens. Put the clear solution aside to cool.

You are perhaps fond of sweet tea and have sometimes dissolved a great many lumps of sugar in a cup of hot tea. Have you ever wondered whether there is any limit to the number of lumps which could be dissolved? As a matter of fact, there is a limit. As you found in experiment 31, hot water will dissolve more alum than cold water, but the extra alum will not remain dissolved when the solution cools. You have probably noticed the bright regular-shaped pieces of alum which separated out. We call them crystals.

32. Using the same method as in experiment 31, try to make crystals of some of the following substances:

salt; alum; copper sulphate.

You will find it convenient to leave the solution to cool in a beaker or in an evaporating dish.

33. Choose a well-shaped alum crystal. Suspend it by a piece of cotton in a saturated alum solution, and watch each day what happens.

Discussions.—(*a*) Some firms sell what is called Soluble Cocoa. How would you test whether the cocoa is really soluble?

(*b*) If you were given a mixture of salt and sand, how could you separate the sand from the salt?

(*c*) How could you find what fraction of a given sample of soil consisted of soluble salts?

(*d*) Plants only feed on the soluble salts of the earth. Why?

(*e*) How would you test whether a substance was only slightly soluble in water?

Notebook Exercise.—Add as many examples as you can to the following lists:

Important dried foods	*Crystals used in the home*
Raisins	Sugar
Biscuits	Soda

One interesting fact about most salts is that they will not burn away when heated. Have you ever examined closely the ash which remains in the fire-grate after a fire has burnt out? It is the earthy or mineral part of the coal, and it consists of salts which trees took out of the ground as part of their food thousands of years ago.

You can now test whether various foods do contain salts.

34. Place some small pieces of different foods on a small sheet of asbestos, and heat them over a bunsen burner. Examine what is left after you have burnt up the food as completely

as possible. (Asbestos is suggested for this experiment because it will not burn even if it is made very hot indeed. It is also good for this experiment because it will not crack when heated nor will it in any way alter the foods placed on it. If you have no asbestos in school, can you think of a suitable substitute?)

Make a list of those foods which appear to contain no salts, and those which seem to be richer in salts. Compare your results with the facts given in fig. 8, p. 25.

35. Carefully boil away some drinking water and notice whether any salts are left behind.

It is clear from your experiments that our food contains only very small quantities of salts. We cannot, however, keep healthy unless we have these salts, and that is one reason why it is important to include plenty of milk, fruit and vegetables in our daily diet (see fig. 8). It is much better to take salts in this way than to take them in medicines bought from the chemist.

Energy-giving Foods: Starch and Sugar.

You generally think of starch as being useful for stiffening collars. It is, however, a very important part of our food, and the starch used on washing-day was, as a matter of fact, extracted from such eatables as potatoes, maize, rice and sago. You can test for yourselves whether the things you eat do contain starch. First of all, you need to know how to recognize starch, for you cannot be sure by merely looking at it. And you certainly cannot tell whether foods contain starch by merely looking at them or by tasting them.

36. Take a little starch and powder it up. Shake it up with a little cold water in a test-tube and then add a little iodine solution to the mixture. What happens?

No other substance has yet been found which behaves like this with iodine. Iodine acts as a detective for starch and we can use it therefore as a means of finding whether starch is present.

37. Test some of your daily foods to see if they contain starch.

Make a list of the foods in which you find starch, and compare your results with the facts given in fig. 8, p. 25.

38. Grate up a raw potato; put it in a basin with a little cold water, and pulp it up. Pour off the milky liquid and allow it to settle. What is the white sediment?

Before our bodies can make use of the starch we eat, it must be changed into a soluble substance. This is done inside our bodies when food is digested, and the soluble substance made from the starch is sugar. You see therefore that the starch we eat in potatoes and the sugar we eat in puddings are useful to us in the same way. Their chief use is to supply us with energy so that we ourselves can move about, and so that we can move other things about by pushing or lifting or pulling them. The more active you are, the more starch and sugar you need. If you eat more of these foods than is necessary to supply you with energy, the surplus sugar is stored up in your body as fat. This is the reason why people who eat a great deal of starchy food generally become fat, especially if they do not take plenty of exercise. A reasonable amount of fat is a useful reserve on which you can draw in times of emergency, perhaps during an illness when you are unable to take ordinary foodstuffs. The camel's hump is another interesting example of a useful storehouse of fat.

Where do Starch and Sugar come from?

So far, we have learnt that, in order to live, it is necessary (1) to breathe the air which surrounds the earth; (2) to drink the water which floats on its surface and which trickles into it; (3) to eat some of the salts which form part of the earth itself. Now we have learnt how important it is to eat starch and sugar. Where do these come from?

Notebook Exercise.—Add as many examples as you can to the following lists:

Natural Sources of

(a) Sugar	*(b) Starch*
Sugar cane	Potato
Ripe fruits	Maize

You see from the above lists that starch and sugar come from plants which were once alive, growing in the earth and its surrounding atmosphere. Have you ever realized that without plants we could not exist, that we are absolutely dependent on them for the food which gives us energy to move about? Since they are so extremely important we are going to study how they feed and grow, how they manufacture starch and sugar for us and other living creatures to eat.

39. Soak some French beans in cold water overnight. Test one of the beans for starch.

Remove the skin of another bean, and having split it into two parts, examine it carefully. Make a sketch of what you see.

Fill an ordinary glass jam jar with moist soil. Press some of the beans about half an inch deep into the soil, working them to the sides of the jar so that they can be seen from the outside. Put the jar in a dark cupboard in a warm place. Examine it daily and record by sketching every three or four days the changes which you see. (Remember to keep the soil moist. Why?) Underneath your sketches write answers to the following questions:

Which part of the bean begins to grow first?
Which way does it grow?
Which parts of the bean become the seed leaves? Which part becomes the root of the plant?

When the seed leaves have appeared, keep the jar in a warm sunny place. Continue making your regular sketches and describe in your own way what happens to the seed leaves.

You probably learned in Nature Study lessons that all seeds do not grow in exactly the same way, and you may like to repeat experiment 39 using other seeds, such as peas, maize, sunflower, mustard, cress.

While waiting for the results of your experiments on growing seeds, you have a good opportunity of revising back work and of completing your notes.

Notebook Summaries.—Complete the following paragraphs:

F. 2. EVAPORATING AND BOILING

(boiling; bubbles; disappear; evaporating; Evaporation; looking; quicker; surface; water; water vapour.)

In warm, dry weather, water is continually being changed into -1-. We say the water is -2-. -3- goes on quietly and invisibly from the -4- of the water. We know, however, that something is really happening because if water is left to stand, it will in time -5-.

A -6- way of changing -7- into water vapour is by -8- it. The -9- of vapour rise quickly through the water, so that we can tell by -10-, whether water is boiling or not.

F. 3. SOLUBLE AND INSOLUBLE SALTS

(dissolve; filtering; insoluble; powdered; separated; shaken; warmed.)

In order to dissolve a soluble salt quickly in water, it should first be -1-. Then it should be -2- up with the water, and if necessary the water should then be -3-. Salts which will not -4- are called -5-. If an insoluble salt is mixed with water, it can be -6- from the water by -7-.

Notebook Exercises.—Describe in your own words (*a*) how you made crystals from powdered alum, (*b*) how you made starch from a potato, (*c*) how you tested whether bread contained starch.

The Wonders of Plant Growth.

The bean seeds we studied in experiment 39 looked at first as lifeless as bits of dry wood, but under the influence of warmth, moisture and air in the soil, they showed they were really alive. One part pushed downwards into the soil, and another part grew into a stem with leaves and branches. If you look at a bean plant grown in the open ground and think about it, you cannot help being struck by the wonderful way it has grown. (Still more wonderful is the growth of a mighty oak tree from a tiny acorn.) Soon the bean plant bursts into flower; the flowers die away and bean pods grow—food for us to eat. We must remember, however, that the first purpose of the growth of plants is not to supply us and other living creatures with food. The new beans which grow in the pods are first of all necessary to provide new bean seeds, for it is clear that if this were not done, bean plants would soon be seen no more on the earth. Plants grow and have flowers and seeds in order that other plants of the same kind may grow after the old ones are dead and gone. This wonderful round, or as we say, cycle of change, is continually going on—seeds producing plants, plants producing flowers and seeds, seeds producing plants again, and so on. A similar cycle is seen in all living things, in animals as well as in plants. Fortunately, plants grow so well that, in addition to producing enough seeds to make sure that new generations of plants will grow up, they also produce supplies of food for us and other living creatures. This would not be so if man merely left plants to grow wild, so that you see what an important work is being done by farmers, and by scientific workers who are continually striving to discover new ways of helping farmers to grow bigger and better crops.

From fig. 8, p. 25, you see that nearly three-fifths of the bean consists of energy-giving starch. Does the growing bean do any work? Strange as it may seem, growing is hard work. The growing bean has had to push aside the heavy soil; it has had to raise its seed leaves and stem to the light of day. This is work requiring energy, and the bean plant starts by using the supply of starch which, as you found, the bean seed contains. But this cannot go on for ever, for a bean seed can only contain a very small supply of starch. Again, where did the parent plant get the starch from, which is stored up in the seed? Try to answer this question before you read on. There are only three answers possible. Perhaps (*a*) the plant gets the starch from the soil; or perhaps (*b*) it gets the starch from the air; or perhaps (*c*) it makes the starch from substances it gets from the air or soil or from both of them.

The following experiment will enable you to decide whether answers (*a*) and (*b*) can be correct.

40. Test soil and air to see if they contain starch.
(In order to test air, shake up some iodine solution with air in a test-tube.)

Before we can check answer (*c*) we must find out more about starch.

41. Heat some powdered starch cautiously for a few moments on a piece of asbestos. Watch the changes which take place. Does starch contain any earthy salts?

When you heated starch you noticed that it turned black. This black substance is carbon; it is the same black stuff we see in charcoal, soot and coal. It is one of the substances which must be present before starch can be formed. In order to make starch, the plant must therefore obtain supplies of carbon. Think of the pounds of charcoal which could be obtained from the wood of a tree, and remember that practically all this charcoal is carbon which the tree has obtained from somewhere during the years it has been growing. Where does the carbon come from? You may perhaps think at first that the most likely place is the soil. Careful experiments, however, have proved that a tree does not at any rate get much carbon from the soil. A willow tree was once planted in a known weight of soil. In five years it grew so that its weight increased from 5 to 169 lb. It must have obtained many pounds of carbon. However, the soil, in which it was grown, was found to weigh only 2 oz. less than it did at the beginning. The tree must have got the carbon from the air! Does air contain carbon? You think at once of all the smoke and soot it contains. This is, of course, not the secret we are seeking. You have learnt already that smoke prevents plants from growing by clogging up the stomata in the leaves. Plants and trees grow best in clean air in the country. Can you think of anything in clean air which does contain carbon?

Now try the following experiments:

42. Test the leaves of a growing plant to see if they contain starch.

Choose some leaves of a plant growing in a sunny position. (Nasturtiums are suitable.) It is necessary, before using the iodine, to remove the green colour from the leaves. This is done by boiling them in water as soon as they are gathered, and then putting them into methylated spirits until they are bleached. Wash off the spirit in clean cold water, and then put the leaves in a weak iodine solution. Hold the leaves up to the light to see the colour.

43. Take a small plant growing in a pot and first test one or two of its leaves for starch as in experiment 42.

Then place the plant and pot under a bell-jar together with a saucer containing a few pieces of caustic potash. This substance will absorb all the carbon dioxide from the air in the jar.

Leave for two or three days and test the leaves for starch again.

These experiments show that there is starch in the green leaves of a plant growing under ordinary conditions in air, but that there is no starch in the leaves of a plant growing in air from which all the carbon dioxide has been taken. We may therefore conclude that carbon dioxide is necessary to enable plants to make starch. This is the secret we were seeking: growing plants and trees obtain the carbon for making starch from the carbon dioxide in the air. Now you can understand why, in spite of the continual breathing of millions of plants and animals, the air never gets overcharged with carbon dioxide. This gas, which is really the waste product ot the breathing of all living things, is food for growing plants. Out of this food, green plants manufacture starch. This is the starch which we and the animals eat, and which supplies us with energy. Some manufacturers are very clever in making use of waste products, but no human invention is as wonderful or as economical as this excellent arrangement of Nature whereby the waste gas breathed out by plants and animals is used again as food by plants, and made into energy-giving food for animals to eat.

In Chapter II we learned that when plants are breathing they give out carbon dioxide. Now we learn that when plants are feeding they take in carbon dioxide. In Chapter II we also learned that plants are like us—as long as they are alive they must keep on breathing all the time without stopping. Are plants also like us in feeding? We are not always taking in food. Are there any times when plants stop feeding on the carbon dioxide in the air?

44. Test a leaf of a growing plant for starch. Shut up the plant for three days in a dark cupboard, and then test one of the leaves for starch.

45. Over a portion of a leaf growing on a plant fix a band of thick paper. (" Silver " paper will do very well.) Put the plant in the sunshine during the day. After three days remove the band and test the leaf for starch.

Notebook Summary.—Complete the following paragraph:

F. 4. SALTS

(dissolved; earth; insoluble; Rivers;
salty; Marble; sediment; soluble.)

Salts come from the -1-. -2- wash them out of soil; those which are -3-, dissolve in the water and it is these -4- salts which give sea-water its -5- taste. Those which are -6- either remain visible in the water or they settle to the bottom as a -7-. -8- is a common example of an insoluble salt.

Notebook Exercises.—(*a*) Write all you can about the ashes left in the fire-grate.

(*b*) How would you test whether a given sample of food contained salts?

(*c*) Describe experiment 42.

The results of experiments 44 and 45 show you how necessary sunlight is to help plants to make starch. Carbon dioxide, a waste product of breathing, is being given out by all living things day and night, but it is only when plants are in sunlight that they feed on this waste and use it to make starch.

Discussions.—(*a*) Why do plants not thrive when they are overcrowded? (*b*) Why do most plants grow sickly in dark corners of the garden? (*c*) When do plants (i) reduce the amount of carbon dioxide, (ii) increase the amount of carbon dioxide in the air?

Plants and Soil.

Carbon dioxide is not the only food which plants need. You know from your Nature Study lessons that plants feed also by means of their roots, and you know that it is necessary to keep soil moist if plants are to grow. The water which soaks into the ground dissolves the soluble salts in the soil, and it is this very weak solution which the roots absorb, and which is carried to all parts of the plant. This is how the health-giving salts get into fruit and vegetables. Plants are continually feeding on the watery solution in the soil. Where does all the water go? These experiments will help you to find an answer:

46. Test a leaf of a plant for starch.

Put the plant into a pot of dry soil and leave it without water for several days. Test the leaves for starch again.

47. Weigh a handful of freshly cut grass. Dry it in a warm oven for half an hour. Weigh it again and find the percentage decrease in weight.

48. Place a test-tube round a leaf of a growing plant so that the leaf is wholly within the tube. Plug the mouth of the tube with plasticene so that it is air-tight.

Examine the test-tube regularly.

Notebook Exercise.—Study figs. 9 and 10 and practise doing them from memory. When you can do them perfectly, put them in your notebooks.

Carbon dioxide alone is not sufficient for the making of starch by plants; experiment 46 shows that a supply of water is also necessary. From these two common substances, water out of the soil and carbon dioxide out of the air, plants make starch. What a wonderful transformation! A colourless gas and a colourless liquid are combined together by green leaves growing in sun-

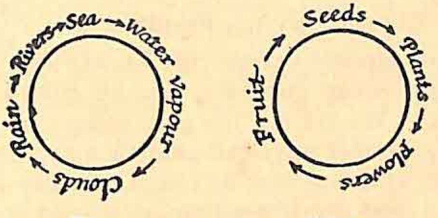


Fig. 9 Fig. 10

Two Cycles of Change in Nature

light, and the result is starch, a white solid. On the next sunny day when you see a field of green grass, or a tree in full leaf, you will be able to think of the marvellous way in which food is being manufactured, without any visible sign that anything is happening. No noise, no smoke! How different from some of the food factories invented by man!

It is not only for making starch that plants need water. Starch made in the leaves is insoluble and before it can be moved to other parts of the plant, it has to be made into sugar which is soluble. The sugar then dissolves in the watery solution which the roots have absorbed from the soil. This solution, containing both salts and sugar, we call sap. The sugar is then taken in the sap to all parts of the plant, some of it to be used up at once for growing, some of it to be changed again into starch or oil, and stored up for future use in roots, bulbs, tubers, seeds or fruits.

Some of the water absorbed by the roots is used neither for making starch, nor for carrying sugar. As you learned from experiment 48, it escapes into the air as water vapour. In dry regions, plants could not live, if they lost in this way a large proportion of their scanty supply of water. Consequently, their leaves are often protected by a thick skin or by hairs. Sometimes the leaves grow in the shape of spines with a very small surface exposed to the air; or they grow very thick so that they can store a good supply of moisture.

Another Energy-giving Food: Fat.

We have already learnt that starch and sugar, not required for other purposes, can be stored up in the body as fat. We are not the only living creatures which store up fat in this way. All animals make fat, and some animal fat, such as suet and lard, we use as food for ourselves. Bees are interesting because they are able to make large quantities of fat out of the sugar they get from flowers. They use this fat (beeswax) for making storehouses for sugar (honey).

You can tell by looking at meat and bacon whether it is fatty. Looking at food is, however, not a sure test for fat, because the fat is sometimes so mixed up in food that you cannot see it. Do the following experiment:

49. Put a small piece of fat meat on a piece of plain white paper. Warm it gently. Remove the meat and examine the mark left.

On the same piece of paper, put a drop of water. Compare the marks made by fat and by water. Examine them again next day.

You know that solid fat can easily be changed into liquid oil by warming it. We say that the fat has melted. A very common fatty food is butter, which is made by churning cream, the fatty part of milk. You would not guess by looking at milk that it contained fat. This is because the fat is in the form of millions of very tiny separate globules, floating about. When milk is left to stand, these globules, being lighter than the rest of the milk, rise to the top and you can see them as a layer of cream. The globules are still separate, and before they can run together to form solid butter, it is necessary to burst them. This is why the cream has to be shaken in the churn. You can make a little butter by shaking up cream in a bottle.

Experiment 49 has given you a rough and ready test for fat. Liquid fat runs into the pores of paper and makes a grease-mark; unlike water, the oil does not evaporate if left exposed to air.

50. Test small samples of common foodstuffs to see if they contain fat. The following are suitable kinds: nuts; herring; lean meat; salt; haricot beans; egg yolk; white of egg.

A convenient way of applying heat is to put the food between two pieces of blotting paper and use a hot iron. Crush the hard foodstuffs before heating.

Compare your results with the facts given in fig. 8, p. 25.

You have probably noticed that there are two kinds of fatty foods—those which come from plants and those which come from animals. Some plants, nut trees and cotton plants for example, store fat in the form of oil in their seeds; other plants, the olive tree for example, store oil in their fruits. In every case, you will remember that the fat is made from starch which is made by the leaves out of carbon dioxide and water. Animal fat, too, comes from the same substances, for it is made from the starchy vegetable foods which the animals eat. When you eat butter next time, you can think that it was once carbon dioxide in the air and water in the soil. Blades of grass changed these substances into starch; cows ate the grass and changed the starch into fat. The butter you eat will supply you with energy to enable you to move about; any surplus will be stored up as fat. Margarine is artificial butter. There are many ways of making it but it is always made out of animal or vegetable fat or a mixture of both.

Petroleum (rock oil) is a fat, but it is not good to eat, though as we shall learn in a later book, man has invented ways of getting and using energy even from this kind of oil. As you know, it is found in the earth in various places. How did it get there? Some men of science believe that, like palm oil or linseed oil, it is a product of plant life. If this is so, rock oil was made from the same kind of substances as coal, the other important fuel found in the earth. Other men of science think that, like cod-liver oil, petroleum comes from fish. Even if this is the true explanation, the story is still the same, for the fish can only have made the oil out of the starchy plant food which they ate. How much we owe to plants and sunlight! Plants growing in our present sunlight provide us with starch, sugar, and fat to eat; they are the source of our bodily energy. Plants growing in sunlight thousands of years ago have left us a plentiful supply of coal and oil to burn; they are the source of the energy we get by means of engines.

Notebook Exercise.—Add examples to the following list:

Fats and Oils used in the Home

From plants	*From animals*
Olive oil	Butter

Body-building Food: Protein.

We have studied four kinds of food: (*a*) water which forms four-fifths of our bodies; (*b*) salts which form a large part of our bones and teeth and are also present in our blood; (*c*) and (*d*) starch, sugar and fats which supply us with energy and go to make the fatty parts of our bodies.

What foods are necessary for the growth and repair of our bodies? The answer is proteins. Fig. 8 (p. 25) shows that, of the common foods we eat, eggs, bread, fish, meat, and cheese are the richest in protein. Among foods obtained from plants, peas, beans, and nuts contain the most, though proteins are present in small quantities in most vegetables. All animals can make fat out of starch and sugars but no animals can make protein; they must eat it ready-made. Most people get their supply of protein by eating fish and meat, and the creatures which provide us with this food get it from the plants they eat. Sheep and cows feed on grass; large fish do, of course, eat little fish, but these little fish feed on huge masses of tiny plants and animals found floating in the sea. You see then that once again we cannot do without plants and sunlight, for plants growing in sunlight are the makers of the essential body-building foods, the proteins. Plants make proteins from starch, sugar, and salts, chiefly nitrates. We shall learn more about nitrates in Book II.

Vitamins for Healthy Growth.

In the days of sailing ships, when voyages sometimes took sailors away from land for months at a time, the men often suffered from a disease called scurvy. It was found that the addition of a little fresh lemon juice to their diet of salt meat and biscuit not only cured the disease but prevented it. It used to be thought that it was the salts in the juice which prevented scurvy, but recently men of science have discovered that this is not the whole truth. The fresh lemon juice contains minute quantities of a substance to which they have given the name of Vitamin C. This substance is also present in oranges and in fresh lettuce and cabbage. By means of experiments on the feeding of animals, chiefly rats, men of science have discovered that proteins, water and salts are not alone sufficient for healthy growth. Without Vitamin A, which is present in milk, butter, cheese, yolk of egg, and green vegetables, you are not likely to escape catching infectious diseases. Vitamin B, which is present in wheat, rice, lentils, and yeast, is particularly necessary for the healthy growth of nerves. Vitamin D, which is present in cod-liver oil, in oily fishes such as herrings, and in egg-yolk, is essential for the proper growth of bones and teeth.

In 1931 men of science made some more very interesting discoveries. They found that there are seven or eight different kinds of vitamins, and though foods contain extremely small amounts, they have been able to extract some Vitamin D. An American experimenter claims to have done something more wonderful still: he believes he has been able to make some Vitamin D out of chemicals, without the aid of plants or sunlight.

It is believed that a plentiful supply of sunlight direct to the skin may make up to some extent for a lack of vitamins in food. We have already learnt how necessary sunlight is for the healthy growth of plants; there is probably a great deal still to be discovered about the value of sunlight for growing animals.

Notebook Summaries.—(*a*) Complete the following paragraphs:

F. 5. Plants and our Food Supplies

(animals; carbon dioxide; die; dissolves; insoluble; new; old; overgrown; plants; produce; roots; salts; seeds; starch; sugar; sunlight; water.)

Plants grow in order to produce –1– from which new young plants may grow to take the place of the –2– ones which in time must –3–. They feed through their –4– on watery solutions of –5– in the soil, and through their leaves on the –6– in the air. From these three substances (–7–, salts, carbon dioxide) plants, under the influence of –8–, make starch and proteins. The –9– starch is changed into soluble –10–. This –11– in water, forming sap. Some of the sugar is used for growth; some of it is stored as –12– again, in roots or seeds; in some plants, part of the sugar is changed to oil which is also stored, sometimes in fruits, sometimes in seeds.

If all –13– were allowed to –14– seeds, and if all seeds grew into new plants, the earth would in a few years be –15–. Far more plants, fruits and seeds are produced than are wanted to keep up the supply of –16– plants. The chief use of the surplus is to provide food for –17–.

(body-building; dependent; energy-giving; fat; feed; food; fruits; health-giving; live; plants; protein.)

Living creatures feed on –1– and on their seeds and –2–. In this way, we get –3– foods (starch, sugars and fats), –4– foods (proteins), and –5– foods (salts and vitamins). We also –6– on animals and in this way we get further supplies of food, especially of –7– and –8–.

Without plants, no creatures would be able to –9– on the earth. We say we are –10– on plants for our –11– supplies.

(*b*) Study the following summary of what you have learnt in Chapters II and III. Write it out from memory in your notebook.

The Essentials of Life

Plants	*Animals*
Air	Air
Water	Water
Salts	Salts
Sunlight	Sunlight
Carbon dioxide	Plants

(*c*) Complete the following table as far as you can:

Vitamin	Where found	Value
A	Milk, butter, cheese, yolk of egg, green vegetables.	Protection against infectious diseases.
B		
C		
D		

Notebook Exercise.—Turn back to the record you made of your meals for a week. Mark the foods with letters according to this plan: E. Energy-giving food. B. Body-building food. W. Water. H.s. Health-giving food (salts). H.v. Health-giving food (vitamins).

(The composition of foods not mentioned in fig. 8 can be found in an encyclopedia.)

What ought we to Eat?

Everyone knows that food is necessary for all living things. You now know the kinds of food that are necessary, and you see that very few of the common foodstuffs are perfect foods by themselves. A diet consisting almost wholly of bread and potatoes would give you too much starch and too little protein and fat. That is why most of us eat meat. Some people, however, are vegetarians. They get protein by eating eggs, or cheese, or such vegetable foods as peas, beans, and nuts. Ordinary vegetables, such as cabbage, contain very little starch or protein, but they are necessary because they supply us with salts and vitamins. Milk contains all the necessary foodstuffs—proteins, fats, sugars, salts, vitamins, and water. It is by itself a perfect food and it would be possible to exist on milk alone. A diet consisting only of milk would not, however, be a good one. One reason is that our teeth would decay for want of use. Another reason is that we cannot obtain full value from food unless we enjoy taking it. A milk diet would be very monotonous. Your daily diet should, however, contain at least half a pint of this most valuable food. The safest general rule for diet is to take a good variety of plain food so that the body may take from it the supplies of the different kinds of material which it needs.

This brings us to the subject of digestion which we shall study in Book II.

Discussion.—Good cheap foods for breakfast, dinner and tea.

Books to Read.—Reserve a page in your notebook for a list of interesting books on science. Here are some titles to start with. In these books, you will find more information about Breathing and Feeding, and about the other subjects mentioned in Chapters II and III.

About Coal and Oil, C. R. Gibson (Blackie).
Discoveries in Chemistry, C. R. Gibson (Blackie).
Coal and the Miner, W. J. Claxton (Blackie).
The Romance of Modern Chemistry, J. C. Philip (Seeley Service).
Science and Living Things, W. B. Little (Pitman).
The Wonders of the Sea, C. Hall (Blackie).

Five-minute Lectures.—We have mentioned many interesting things in Chapters II and III. Choose one of them and collect all the information and pictures you can about it. An encyclopedia will give you a start, and you can often find information in magazines and newspapers. Be ready to give a short talk to the class on your special subject, and be prepared to answer questions from members of your audience.

The books mentioned above will give you ideas for subjects. They contain, for example, chapters with the following titles:

(*a*) Natural waters and what they contain; (*b*) Sugar and starch; (*c*) Fats and oils; (*d*) The adulteration of food; (*e*) Liquid air; (*f*) Gas that extinguishes flame; (*g*) How the winds rule the ocean; (*h*) Divers and diving devices; (*i*) Fishing and fisheries.

Other subjects to choose from are:

(*j*) Hibernating animals; (*k*) Worms; (*l*) Whales; (*m*) Frogs; (*n*) Camels; (*o*) Dried foods; (*p*) Condensed milk; (*q*) Common salt; (*r*) Filters; (*s*) Water-works; (*t*) Asbestos.

CHAPTER IV

Moving

We have learnt in Chapters II and III that all plants and animals, as long as they are alive, must keep on breathing and feeding. We have noticed too that they must all move. Watch how your classmates are continually on the move. All over the surface of the earth, there are countless living creatures all moving about. Look up in the air and watch the birds soaring gracefully overhead, and winged insects darting hither and thither. If we could see down into the soil, or into the depths of the ocean, the same kind of picture would meet our eyes. All creatures, wherever they may live, must move about, if only to obtain and eat their food.

Try to sit perfectly still for a minute. You find that however hard you try to stop yourself moving, you simply cannot do so. Even if you succeed in keeping your head, trunk and limbs still, your body is still making many movements.

Even a plant moves. Think how much an oak tree grows during its lifetime. It cannot do this without stretching out and lifting up its branches into the sunlight which is so necessary to enable it to feed. These movements in the air are made very slowly—so slowly that you cannot see them merely by looking at the tree for a short time. Perhaps you have seen films which show growing plants stretching towards the light. Such pictures reveal in a few seconds, movements which plants take days to make, and you see that such movements are just as real as those you make yourself. More wonderful still are the movements which growing things make in the ground. What tremendous force is necessary for a tree to push its giant roots through the hard heavy soil! And how marvellous it is that the slender thread-like roots of a plant are able, in their search for food, to tunnel their way underground! Think about these wonders of moving, next time you are digging among roots in the garden. Although plants cannot change their positions as you can, they must move in order to live, up into the air and sunlight, down into the moist soil. And all the time another movement is going on—the movement of sap which, as we learned in Chapter III, is carrying food to all parts of the plant. Have you ever thought how wonderful it is that, in a tree, the watery solution of earthy salts is lifted from the deepest roots to the topmost branches?

It is interesting to notice that plants can get all the food they need while remaining rooted in one place. As a general rule, we and other living creatures have to move about to get our food. There are, however, exceptions to this rule. Young creatures start life in very much the same way as plants do. At the very beginning, the only movements they make, like those of the plant, are growing and feeding movements. A chicken is first of all a tiny speck inside an egg. For the first three weeks of its life, it lives and grows inside its shell. It feeds on the protein, fat and water contained in the white and yolk of the egg, just as the little bean plant begins by feeding on the starch contained in the bean. But when the chicken hatches out, it is able, almost at once, to move about and get food for itself.

All insects start growing in much the same way, but the eggs in which they begin their lives, are often so small that they contain hardly any food. The result is that the creature which is hatched out is very tiny and helpless. It cannot at first move far to get its food and, if it is to live, a supply must be nearby. This is why butterflies and moths lay their eggs on just the right kind of leaves for the tiny caterpillars to eat. The housefly also lays its eggs in exactly the right place—on decaying food and refuse; for this is the stuff on which the helpless larvæ feed when they are hatched. Those birds which begin life in small eggs are also helpless at first. They are unable to fly about and it is not possible to surround them with suitable food. The parent birds therefore move about, catch the necessary caterpillars, flies and worms, and drop them into the open beaks of the young ones in the nest.

Men and Machines.

Although many young creatures cannot at first move far to get food, they very soon become strong enough to do so. Insects, animals, and birds soon learn to make use of the machinery of their bodies, so that they can move themselves in ways suited to their manner of living. They are also able to move many parts of their bodies separately. Man is more wonderful still, for in making movements, he soon learned not to depend only on the machinery of his own body. In moving things, he found it helpful to use poles and logs. By using poles as levers, he really made his arms longer and more powerful; by using them as stilts, he increased the length of his legs. Perhaps as a result of watching logs rolling, he invented wheels, and thus enormously increased his power of moving. Then he began to use levers and wheels together. From that time, one invention followed another, until to-day we find that much of the work formerly done by hand, is being done more and more by intricate man-made machines.

Man has also shown his superiority over other living creatures by learning not to depend so much on his own strength when he wanted to move things. It is true that many living creatures allow themselves to be moved along by the force of the wind or running water, but man has learnt how to use these forces to drive machinery which does all kinds of work. Again, very early in his history, man learned how to employ animals such as the ox, camel and horse to do work for him. To-day, however, we find these slow beasts of burden being rapidly replaced by man-made engines which are able to exert forces far greater than can be exerted by the living engine of any animal.

You see then that many movements are made by machines, either living machinery like arms, wings, and legs, or artificial machinery like levers and wheels made of wood and iron. What is it which moves machinery? What enables you, for example, to move your arms and legs? Sometimes you feel as if you could go on playing, pushing and pulling, lifting and kicking, without ever wanting to stop. You say you are energetic, or that you are full of energy. This is what moves machinery of all kinds—*energy*. It is often obtained from fuels by means of engines. Man-made engines use such fuels as coal, oil and petrol; living engines use the starch, sugar and fat of food. If you took no food for a long time, you would feel weak: you would have very little energy, hardly enough perhaps to raise your arms.

51. Raise and lower your right forearm several times, while grasping the upper arm with your left hand. What do you feel?

Stand up and place your hand on the back of your thigh. What do you feel as you bend your knee and bring your heel up towards your hand?

"Heels raise—lower." Feel your calf as you do this exercise.

Muscles, the Movers of Living Machinery.

Each time you made a movement, you felt some of your muscles get hard and swollen. This is what happened. You decided, for example, to raise your forearm. A message travelled along nerves from your brain to your arm muscles. Immediately, the muscles in front of your upper arm got thicker and shorter; we say they contracted. These muscles B, are attached at one end to the top of your upper arm and shoulder, and at the other end to your forearm (see fig. 11). When they contract, only one thing can happen. Up comes your arm. Work out for yourself what happens when you decide to lower your forearm.

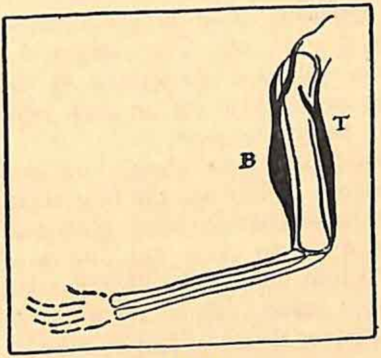


Fig. 11

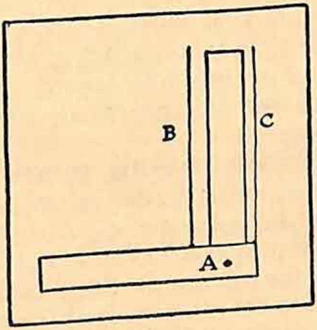


Fig. 12

Fig. 12 shows you a simple model which you can make in wood or cardboard to help you to understand the action of your arm muscles when you move your forearm. It consists of two pieces loosely jointed at A by a screw or pin. Two strings, B and C, are attached to represent the muscles. The model is only a very rough representation of your arm. The actions of your muscles are far more complicated than those of the string, and your elbow is much superior to any joint which you can make with screws or pins.

Without our muscles we should be unable to make a single movement. They are the best servants we have; each set of muscles has its own particular job to do, and is always ready to carry out our orders promptly. If you tried to find out all the different kinds of movements you could make with all parts of your body, you would soon discover that you had an almost endless task. It would, however, give you some idea of the wonderful muscle equipment you are continually using, for even in the tiniest movement, some muscles must get longer (or relax) while others contract. It is the pull which muscles exert when they contract which causes movement.

The way to make your muscles stronger is to exercise them. The next time you are doing physical exercises, you should notice where you can feel the muscles at work, and which muscles get tired, as you make the various movements.

Every time a muscle contracts, it uses energy, just as a piston rod does when it moves up and down in a cylinder. The chief difference is, as we have seen, that the energy of piston rods comes from the fuel the engines consume, while the energy of our muscles is obtained from the food we eat. But in both cases it is energy which is used when movements are made. When you see men moving earth, or women scrubbing tables, you say they are working. Men of science use the same word, “ working ”, but they say you are doing work whenever you are moving anything. If you move yourself into a bedroom by walking upstairs you have done some work; so you have, if you push a handcart, ride a bicycle, or kick a football. In the same way, we can talk about a steam engine doing work when it moves a train. Energy is always necessary if work is to be done. We may say therefore that energy is the capacity for doing work. All kinds of machinery, living and non-living, use energy when they move things, that is, when they do work.

When you use energy to push something, you say you are using force. This is the name used by men of science, but they call pulls as well as pushes by the same name—forces.

Notebook Summaries.

M. 1. MOVING

(able; animals; become; food; grow; increased; lives; living; machines; move; plants; rooted; unlike; Young.)

All -1- things, both -2- and animals, must move in order to feed and -3-. -4- creatures, at the beginning of their -5-, are like plants; they absorb their -6- without having to -7- about to get it. As they grow up, they -8- more and more -9- plants, for instead of being -10- to one spot, they are -11- to move about.

Man has -12- his ability to move by employing -13- and by inventing -14- and engines.

M. 2. ENERGY AND WORK

(Energy; food; living; move; movements; muscles; pull; push; relaxing; work.)

The energy required to enable -1- things to -2- is obtained from the -3- they take in.

All -4- of living creatures are caused by -5- contracting and -6-.

Energy is used when we -7- or -8-, that is, when we exert force. If force causes something to move, men of science say that -9- has been done. -10- is therefore always necessary if work is to be done.

M. 3. MACHINES, ENERGY AND ENGINES

(coal; fuels; horses; human beings; petrol; Trains; water-wheels; windmills; Wings.)

All machines are moved by energy.

Many machines are moved by energy obtained from –1– by engines:

e.g. Arms by energy obtained from food by –2–.
–3– ,, ,, ,, –4– ,, steam engines.
–5– ,, ,, ,, food ,, birds.
Motor-cars ,, ,, ,, –6– ,, petrol engines.
Carts ,, ,, ,, food ,, –7–.

Some machines, e.g. –8– and –9–, are moved by the energy of moving air or water.

What makes Things Heavy?

When you lift a scuttle of coal you have to exert a strong pull. You can do this because you have muscles ready to contract, and a supply of energy to enable them to do so. The pull you exert is necessary because the coal and scuttle are heavy. What makes them heavy? If you answer, "Their weight", someone may well ask, "What is weight?"

Weight is a force—a pull exerted by the earth. You know that objects which you drop fall straight to the ground. The earth exerts a pull on them and down they go straight towards its centre, until they are stopped when they meet the ground. This pull is called the force of gravity. As a matter of fact, all bodies in space exert a similar pull on one another. A cricket ball thrown into the air exerts a very small pull on the earth, but since the ball is so small compared with the huge bulk of the earth, its effect is so extremely tiny that for practical purposes we need not take any notice of it. But when we consider the movements of large bodies, such as the sun and the moon, the earth and the other planets, we must take into account the pulls which they exert on one another. These are the forces which keep the moon in its path round the earth, and the planets in their orbits round the sun.

The strength with which the earth pulls any ordinary object is most easily measured by a spring balance. We say we are measuring the weight of the object. When you say you weigh 70 lb. and I say that I weigh 140 lb., we mean that the earth is pulling you towards its centre with half the force it is pulling me. The force pulling you is 70 lb. wt.; the force pulling me, 140 lb. wt.

It is interesting to know that the farther you get away from the earth's centre, the less will be the strength of the earth's pull. Your own weight, for example, will be a tiny bit less on the top of a hill than at the seaside.

You must not imagine that the force of gravity is the only force which we find working in the world. There are forces working in all directions. Look at the light pendant in your classroom. The globe and fittings probably weigh at least two or three ounces; that is, the earth is pulling, or as we say, attracting them with a force of two or three ounces weight. There must be another force to keep the pendant where it is. This second force is working upwards and is equal to the first one; that is, the fitting in the ceiling to which the pendant is attached must be pulling upwards with a force of two or three ounces weight. Again, consider a sailing boat being pushed through the water by the wind. Here there is a force working along the surface of the water.

Another important force is one you bring into action when you spin or whirl things round and round. When, in physical training lessons, you swing the bean bag round on the end of a rope, it seems to pull away from your hand. This pull is called "centrifugal force". You can easily see that it is just as important as gravity in keeping the earth in its orbit. If "centrifugal force" were not in action, the earth would rush into the hot sun; if gravity did not act, the earth would rush away into cold space.

Notebook Summary.

M. 4. THE FORCE OF GRAVITY

(earth; fall; force; gravity; measure; orbits; planets; pull; pulling; spring-balance; tiny; weight.)

Every object is -1- every other object. The pull of one brick on another brick a few inches away is too -2- to be noticed, but the -3- which the -4- exerts on a brick is easily noticed. It is this pull which causes a brick to -5- when you drop it. We -6- the pull of the earth on an object when we find its -7- by means of a -8-. The -9- of attraction which all objects exert on one another is called the force of -10-.

This force keeps the moon and the -11- in their -12-.

Notebook Exercise.—What forces are acting on a pound weight held in your hand? What is roughly the measure of the force you exert when you are (*a*) keeping the weight still, (*b*) lifting it slowly, (*c*) lowering it again?

Discussions.—(*a*) How does a cream separator work?

(*b*) Why are mudguards necessary on bicycles and cars?

(*c*) What causes the tides?

(*d*) Making and using a plumb-line.

How Work is Measured.

We have learnt that we are doing work when, by exerting force, we move things about. Who does more work—a girl who lifts 7 pounds of sugar from the ground on to a shelf 4 ft. high, or a girl who lifts 14 pounds from the ground on to a stool 2 ft. high? The second girl has to pull harder but the first girl has to move the weight farther. In order to measure the work, we must take into account both the distance the sugar is moved and the strength of the force needed to move it. When you lift a pound weight one foot upwards, men of science say you have done a foot-pound of work. Measuring work in this way, we see that the two girls each did the same amount of work, viz. 28 foot-pounds.

Work mentally the following problems:

(i) How much work does a man do in lifting a bag weighing half a hundredweight from the floor to a shelf 5 ft. high?

(ii) How much work has been done when you step from the floor on to a bench 2 ft. high?

(iii) A girl whose weight is 70 lb. runs up a flight of 12 steps each 5 in high What amount of work has she done?

You have to use energy when you " lift things down ". If you take down a saucepan weighing 2 lb. from a shelf, and lower it gently to the gas-stove 3 ft. below, you have to exert a force, which is very little less than 2 lb. wt., to keep the saucepan from falling. You use almost as much energy as you would in doing 6 foot-pounds of work.

A great deal of energy can be saved in houses and workshops by arranging to keep heavy things as far as possible at the level where they are generally wanted for use. Housewives can also lighten their work by arranging their duties to save unnecessary journeys, especially up and down stairs.

Notebook Summary.

M. 5. How Work is measured

(amount; distance; foot; foot-pound; force; lifting;
measuring; move; pound; work; 2; 3; 18.)

The -*a*- of work done when we -*b*- anything depends on the strength of the -*c*- we use, and on the -*d*- the thing is moved. The unit for -*e*- work is the -*f*-; it is the amount of -*g*- done in -*h*- a -*i*- weight upwards one -*j*-. Therefore in lifting 6 lb. weight upwards 3 ft., -*k*- foot-pounds of work have been done. The same amount of work would be necessary to raise -*l*- lb. wt. through 6 ft. or 9 lb. wt. through -*m*- ft.

A Force which stops Things Sliding.

In examples (i), (ii), and (iii) on p. 58, you have considered work done by moving things against the force of gravity. This is an easy force to measure because it is a single force which can be measured by a spring balance. It is very difficult to calculate the work done when you run, or when a car races round a track, for in such examples there are various forces to be overcome. There is, as you learned in Chapter II, the resistance of the air pushing against the runner or the car. There is also a good deal of resistance caused in other ways. The feet and the tyres rub against the road, and there are many moving parts inside the body or the car, all rubbing against one another. When one object is made to slide over another, some resistance has to be overcome. This resistance is called friction.

The more friction there is, the more energy must be used. This is one reason why we oil machinery; it reduces friction, and as we say, the machine works more easily. Everyone who uses machines can save himself work by keeping them well oiled. Nature provides a self-oiling system for our joints where the bony rods of our bodies turn against one another. Designers of machines do all they can to reduce friction; the use of ball bearings is one important device.

Of course, friction comes in useful at times, for example, when we use brakes to stop a moving car. Some friction is necessary also to enable moving things to get a grip; you know how difficult it is to walk on ice, and on a wet day you have perhaps seen the wheels of an engine slipping on the rails when a heavy train starts.

Friction uses up energy which otherwise might be used for getting work done, that is, for moving things about. If you feel the brakes of your bicycle after you have used them coming down a long hill, or the teeth of a saw after cutting a piece of wood, you find they are warm. The energy used in overcoming friction has been changed into heat. Primitive man used to change energy into heat by rubbing together pieces of wood. Later, men used to strike a light by hitting flint and steel together.

When energy is changed into heat by friction, the full amount of work is not being done by the energy used. In this sense, the energy is wasted; it has not however been destroyed, but only changed into another form.

Household cleaning is one kind of work in which friction is very useful. A clear example is the polishing of fire-irons with emery paper. It reminds us that the energy used in overcoming friction does not only produce heat; it also wears things away. Tarnish and dirt we want to wear away, but we are not so pleased when our silver spoons wear thin, and our carpets and bicycles wear out!

Notebook Summary.

M. 6. FRICTION

(energy; heat; resistance; rubbing.)

Friction is the -1- caused by -2-. The -3- used in overcoming friction is changed into -4-.

Notebook Exercises.—(*a*) Make a list of ways in which friction is useful to us for producing heat.

(*b*) Make a list of ways in which friction can be reduced in order to lighten household work.

(*c*) Make a list of examples in which insufficient friction may be a nuisance in everyday domestic life.

Discussions.—(*a*) What are the chief advantages and disadvantages of friction in the home?

(*b*) Why does a stream run faster in the middle?

(*c*) What parts of the following machines would you oil to reduce friction?—sewing machine, mangle, bicycle.

(*d*) What are meteorites? What causes them to become visible?

(*e*) We can make marks on ground glass with a lead pencil, but not on plate glass. Why?

How to lift Heavy Weights by Small Forces.

If we are healthy and eat suitable amounts of foods of the right kinds, we have a wonderful supply of energy for our muscles to use in doing work. Some work, however, is too hard for the muscles of even the strongest man. A glance at a large building in course of erection, with its massive steel girders and heavy materials, will remind you that the energy in our muscles is unequal to the task of doing unaided all the work which is going on. A strong man finds it difficult to lift more than a hundredweight far off the ground, and you have probably often been warned of the dangers of lifting heavy weights. You know, however, that with the aid of a crow-bar you can move things which it would be foolish for you to try to lift with your arms alone. How is this possible?

(In the next three experiments use small forces. Where the lifting is difficult, you must take care not to strain yourself: where the lifting is easy, you must take care not to upset the heavy object you are moving.)

52. There is probably some fairly heavy piece of furniture or a box on the floor of the room. Choose something if possible which stands on feet so that you can get your fingers under. Notice how difficult or impossible it is to tilt the object over using one arm alone. Put one end of a pole on the floor under the object and lift with one hand.

Slide your hand nearer and nearer to the floor where the pole is resting, and notice the difference it makes to the amount of force you have to use. You can easily feel the difference, but if you have a spring balance you can measure it.

53. It is generally easier to press down than to lift up. (Why?) If you put a brick under the pole as near as possible to the object being lifted, you can make use of the " pressing down " method.

As in experiment 52 slide your hand nearer to the place where the pole is resting. (We shall call this resting place the fulcrum.)

54. There is a third way of using the pole. Put one end under the object; make the other end the fulcrum by fastening it down to the floor (a convenient way is for someone to stand on it). Lift up with one hand, and as before try the effect of moving the hand nearer and nearer to the fulcrum.

You can very conveniently repeat experiments 52, 53 and 54 on a small scale like this:

55. For the object to be lifted use any convenient thing which is on the table. For the lever use a pencil. As before, try the effect of exerting the force nearer and nearer to its fulcrum in each of the three positions suggested.

From the above experiments you learn that it is possible to raise a heavy weight with a small force by the simple device of using a lever and applying the force as far as possible from the fulcrum. We shall see the reason for this later on. The bony rods of your body are levers, as you will see if you turn back to fig. 11, and consider again what happens when you raise your forearm.

As it is convenient to be able to refer to the three kinds of levers by special names, they are usually described as levers of the first, second, or third classes as shown in fig. 13.

LEVERS

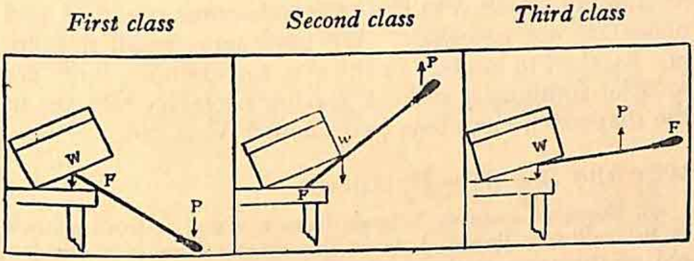

First class *Second class* *Third class*

Fig. 13

Notebook Exercise.—Add as many examples as you can to the following lists, remembering that examples of the three classes can be found in the human body.

First class	*Second class*	*Third class*
See-saw	Wheel-barrow	Sugar tongs

Bone and Steel.

The levers of the body are made of bone; most artificial levers are made of steel. Bone and steel, it will be noticed, are very suitable substances, for they will not bend or crumple up while work is being done. We say they are rigid.

We should remember that our bones are living just as our muscles are. They are rigid because the living substance is embedded in hard earthy salts, mostly lime. You will find it interesting to devise and carry out experiments (*a*) to dissolve the salts out of bone leaving the animal substance behind (use dilute hydrochloric acid); (*b*) to burn the animal substance away leaving the mineral part behind; (*c*) to extract gelatine from bones by boiling.

It is interesting to notice that many small creatures, such as worms, spiders and insects, have no bones; they are called invertebrates. Taking into account their small size, many invertebrates are very strong, but they weigh so little that they only need to exert small forces in order to move. These small forces can be exerted by muscles attached to the creature's outer covering, and bones are not necessary. We have some small muscles not attached to bones. In the eye, for example, there are muscles continually at work making necessary changes in the shape of the eye lens (see Chapter V, p. 76).

Why the See-saw Balances.

56. Suspend a spring balance from a stand or from a hook in the ceiling. Bore a hole in the exact centre of a wooden rod of the same thickness throughout, and about three feet long. By chipping pieces off one end, if necessary, make the rod balance evenly when suspended from the hook of the balance.

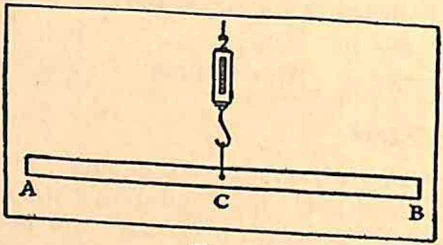


Fig. 14

We have learnt that the force of gravity pulls every object towards the earth. It must be remembered that this pull is acting upon every little part, so that the weight of an object is the grand total of all the earth's pulls on all the little pieces of which the object consists. When we find a place in an object about which it will balance in any position, we are able to overcome the force of gravity acting upon all parts of it by means of a single force at this point. In ex. 56, the single force used is the pull in the spring balance. The point C about which the rod balances is known as its centre of gravity.

57. Balance some common objects in as many positions as you can. Discuss where their centres of gravity are.

58. Using the apparatus of experiment 56:

(*a*) Hang a pound weight somewhere on AC and find where on BC you must hang weights of 1 lb., 2 lb., 3 lb. to get the rod to balance each time. Measure the distances of the weights from the fulcrum C.

(*b*) Alter the position of the weight on AC and repeat the experiment with the other weights. Record your results like this:

AC			BC			(7) Reading of Spring Balance
(1) Wt.	(2) Dist. from C	(3) Wt. × Dist.	(4) Wt.	(5) Dist. from C	(6) Wt. × Dist.	
1 lb.	18"	18	2 lb.			
1 lb.	9"					

Note and discuss the results recorded in columns 7, 3 and 6.

Experiment 58 reminds you of something you learned the first time you played on a see-saw. A little boy can balance a big boy if he sits a long way from the fulcrum while the big boy sits near it. We learn from the results of the experiment something more exact than that. If the big boy is twice as heavy as the little boy he must sit only half as far from the fulcrum, if the see-saw is to balance.

A force applied to a lever tends to turn the lever round its fulcrum. The turning effect of each of the forces applied in experiment 58 depends on (*a*) the amount of the force, and (*b*) its distance from the fulcrum. This turning effect of a force is called the moment of that force, and it is calculated here by multiplying the amount of the force by its distance from the fulcrum. If a lever is to balance, the turning effect in one direction must be equal to the turning effect in the opposite direction.

59. Try the effect of balancing a weight on one arm of your lever by two or more weights at different places on the other arm. Work out the moments of the forces and compare and discuss the results.

You have now learnt that a thing will keep its balance when the moments of all the forces in one direction are equal to those in the opposite direction. You will have noticed that immediately the moments in one direction become greater than those in the opposite direction there is movement, and therefore work is being done. This is of course true for levers of all three classes.

Notebook Summary.

M. 7. MOMENTS

(balances; distance; equal; force; fulcrum; calculated; moment; multiplying; strength; turning; turns; 6; 36.)

When a -*a*- is applied to a lever, the lever -*b*- round its fulcrum. The turning effect of the force depends on its -*c*- and on its -*d*- from the fulcrum. This -*e*- effect is called the -*f*- of the force; it is -*g*- by -*h*- the amount of the force by its distance from the -*i*-. When a lever -*j*-, the moments in one direction must -*k*- the moments in the opposite direction. A force of 3 lb. wt. at a distance of 12 in. from the fulcrum will balance a weight of -*l*- lb. at a distance of 6 in. The moment in each direction is -*m*- units.

Why Things topple over.

You have probably never thought when you accidentally knocked over a milk bottle that you had been working a lever! Discuss these figures:

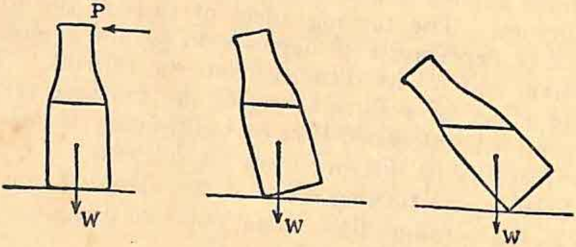


Fig. 15

You knocked the bottle with a force P.

If the bottle moved as far as this, what would happen?

But if it moved as far as this, what would happen?

From the above example, you see that it is the position of the centre of gravity which decides whether an object will wobble back or topple over. If the centre of gravity is over the base, the moment of the weight tends to turn the bottle back again, but if a vertical line through the centre of gravity falls outside the base, the moment of the weight turns the bottle right over. It is the same with baby; when he begins to walk, he often tumbles over because he is unable to keep his centre of gravity within the base provided by his feet.

You see also that the lower the centre of gravity, the more an object can be turned over before it topples. This is part of the reason why housewives often put sand in the bottom of valuable vases; it makes them less top heavy by bringing the centre of gravity lower. Motor-cars are specially built with a low centre of gravity. It is possible to incline the latest type of motor-bus at an angle of 30° from the vertical before it falls over on its side.

It is impossible to keep the centre of gravity of a top exactly over its peg. That is why a top will not stand up. When, however, you start it spinning, gravity is not the only force at work. You bring "centrifugal force" into action, and as long as the top spins fast enough, this force keeps pulling the top up whenever it starts to fall over. You have perhaps read of a mono-rail train which is kept steady by a big revolving top called a gyroscope. The same device has recently been used to keep aeroplanes steady.

Notebook Summary.

M. 8. CENTRE OF GRAVITY

(balance; centre; gravity; weight.)

The -1- of -2- is the point about which an object will -3- in any position. It is the point through which the whole -4- of the object may be considered to pull.

Discussions.—When thinking out answers to the following questions you will find it helpful to remember what you have learnt about levers and moments, and about weight and centre of gravity.

For questions (*a*) to (*d*) you should try by experiment how much force you must exert with your finger to topple the things over. You can also measure with a protractor how far you can turn the things over before they topple.

(*a*) Why is it easy to knock over tall ornaments which have small bases?

(*b*) Why do many household things, like table lamps and babies' chairs, have wide bases?

(*c*) Why do mothers generally give very young children mugs and not tea-cups to drink from?

(*d*) Collect some tea-cups and tumblers of various shapes, and discuss which would be the best for use in the dining-cars of trains or on board ship.

(*e*) What use do you make of the force of gravity when you walk?

(*f*) Why do ships at sea carry ballast?

(*g*) If you have to stand up without support in a swaying train, what is the best position to take? How would you use a walking stick to help you to keep your balance?

(*h*) Why does a man walking a tight-rope usually carry a long pole?

(*i*) Why is it dangerous to lean back in a chair with its front legs off the ground?

The Advantages of Machines.

You can now understand how a lever enables you to do work which you would be unable to do by yourself.

Fig. 16 shows a load of 28 lb. wt. being lifted by a

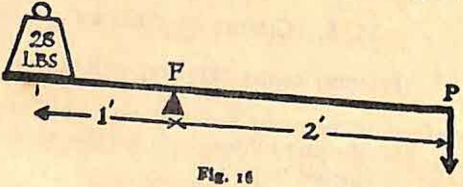


Fig. 16

downward push of P lb. wt. The moment of the force on the left-hand side of the fulcrum is 28 × 1 units, i.e. 28 units. In order to keep the balance, P × 2 units must be equal to 28 units. That is, the push must be 14 lb. wt. If the push P is ever so slightly greater than this, the load will move upwards. Actually, P need not in this case be quite so great as 14 lb. wt. for there is another force acting in the same direction as P, at a distance of 6 in. from the fulcrum. What is it?

If we want to be very exact, we must consider another small force. The lever rubs slightly against the fulcrum and against the weight being lifted, so that some of the energy is not used to lift the weight. What becomes of it?

We shall probably not be very far wrong in this case if we neglect the help we get from the weight of the lever and also the loss we suffer through friction.

We may say then that, using this lever, we are able to move a load of 28 lb. wt. by means of a force of 14 lb. wt. This is an advantage. Men of science measure the advantage by means of the ratio: $\frac{\text{weight lifted}}{\text{force used}}$; this ratio they call the mechanical advantage. In the above example, it is $\frac{28}{14}$, i.e. 2. If a machine had a mechanical advantage of 3, it would mean that, with it, you could move a weight three times as great as the force you used. This is very convenient, but is it not too good to be true? Do we really get this mechanical advantage for nothing—without giving up anything more than the small amount of energy which is always turned into heat when we use levers?

Consider your experiments again. When you moved a weight very easily, you applied a force a long way from the fulcrum. Repeat some of the experiments and notice how far the weight moves compared with the distance your hand moves.

You see that the less the force you have to exert, the greater the distance you have to move your hand. The advantage you gain in force is gained at the expense of distance. This is after all only common sense. You would not expect that if you did a certain amount of work at one end of an iron rod, a greater amount of work would be done at the other end. Remembering that work is measured in foot-pounds, we can argue like this:

You press down at one end of a lever with a force of 14 lb. wt. and move a load of 28 lb. wt. at the other end. If the handle of the lever moves down a distance of 2 ft., you have done 28 foot-pounds of work. If all this work is used to lift a weight of 28 lb., the weight must be lifted 1 ft.

This is the best result you can obtain. In reality, some of the work you do when you move a weight with a lever is used to overcome friction. But even a perfect frictionless machine worked by man could only do the same amount of work as the man does when he moves the machine.

To get a mechanical advantage, it is necessary to arrange that the distance between the fulcrum and the weight should be small, compared with the distance between the fulcrum and the force applied. This is clearly impossible when using levers of the third class. What then is the advantage of levers of this kind? We get a good answer by considering the raising of our forearms. This lever of the third class is shown in fig. 17.

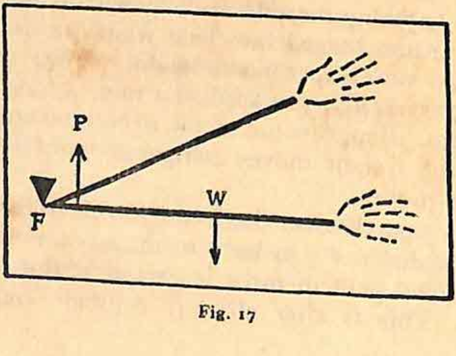


Fig. 17

Answer these questions:

(*a*) What is the fulcrum? (*b*) How is the pulling force obtained? (*c*) Which is greater, P or W? Measure the figure in millimetres and find how many times greater. (*d*) Compare the amount the muscle contracts with the distance the hand moves. (*e*) Compare the speed the hand moves with the speed at which the muscle shortens.

In one way the forearm is a bad machine for you have to exert great force to raise a small weight. You gain, however, in being able to move your hand quickly through a long distance. This ability to move parts of his body quickly was very important to primitive man. It would have been of little use to him if he had been able to lift tremendous weights very slowly. He would have been far too slow and clumsy to survive among the quickly moving animals. Even now it is very useful to you to be able to move your arms and legs quickly to ward off an unexpected blow, or to leap aside in traffic.

Our living machinery has another very important advantage. It may lack mechanical advantage but it can make very delicate movements. Among the most important tasks of our lives is that of learning to control the movements of our muscles so as to perform delicate operations such as lifting a spoon full of soup to the mouth, or handling a pen. Such movements would be extremely difficult if the force exerted by our muscles were amplified rather than diminished by the levers. You can get a good idea of the special advantages of the delicate levers of the third class, and of the powerful levers of the second class, if you imagine yourself trying to crack a nut with the sugar tongs, and to pick up a lump of sugar with the nut crackers.

When it comes to moving heavy things about, we are by Nature rather handicapped. Thousands of years ago man's life was probably quite simple and he needed very little more machinery than that which Nature had given him. As he developed, he began to construct homes and to carry his food about from place to place. These needs obliged him to devise ways of doing heavy work which was beyond the power of his arms. As we have seen, the lever, an extension of his arms, was one of his first inventions. Primitive man's club, the canoe paddle, and the craftsman's hammer, are simple illustrations.

Two important lines of study remain for Books II and III: (*a*) the working of other important machines such as the wheel; (*b*) the way in which engines obtain energy from food and fuel.

Books to Read.—*Iron and the Ironworker*, W. J. Claxton (Blackie); *Triumphs of Invention*, C. Hall (Blackie); *Conquests of Engineering*, C. Hall (Blackie); *Wonders of Transport*, C. Hall (Blackie).

Five-minute Lectures.—The books mentioned above contain chapters with the following titles:

(*a*) A visit to the steelworks, (*b*) Animal transport, (*c*) Metals and tools, (*d*) Machines that feed us.

Another interesting type of subject is to explain how you use everyday levers. The best way is to demonstrate the movement as you talk about it. Try to show the special advantages of the lever you are using and how you can best obtain them. Here are some suggestions:

(*a*) Opening a door, (*b*) Switching on electric light, (*c*) Opening a heavy book, (*d*) Turning on a tap, (*e*) Using a door knocker, (*f*) Digging in the garden, (*g*) Lifting a heavy saucepan, (*h*) Using a typewriter, (*i*) Extracting a nail with a claw-hammer, (*j*) Prising open a packing-case, (*k*) Turning the hands of a clock, (*l*) Pulling a ladder away from a wall, (*m*) Using a coin to open a tin of boot polish.

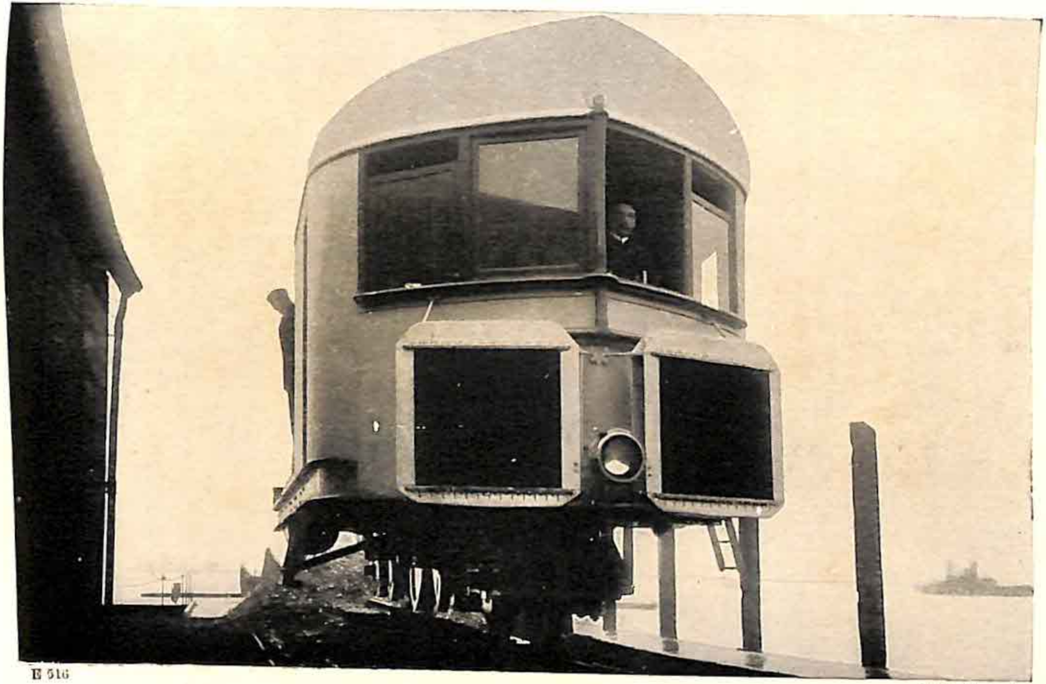
Notebook Summary.

M. 9. THE ADVANTAGES OF MACHINES

(advantage; force; heavy; machine; measured; ratio; small; sufficient; 4; 6.)

By using a -*a*- it is possible to raise a -*b*- weight by means of a -*c*- force. The machine gives us what is called a mechanical advantage. This advantage is -*d*- by the -*e*-,

weight lifted : force used.



E 516

Photo. Topical

A WONDERFUL BALANCER: THE BRENNAN MONO-RAIL CAR

The car is standing still. A gyroscope spinning round inside prevents it from toppling over.

Thus, if by using a machine, a *-f-* of 2 lb. wt. is *-g-* to lift a weight of 12 lb., the mechanical advantage of the machine is *-h-*. If a machine has a mechanical *-i-* of 4, it will raise a weight of 16 lb. by means of a force of *-j-* lb. wt.

(contraction; crow-bar; distance; farther; mechanical; muscles; poor; press; slowly; speed; two.)

A *-a-* advantage is gained at the expense of *-b-* and *-c-*. In lifting a heavy weight by the help of a *-d-*, you have to *-e-* down one end *-f-* than the weight is lifted; the weight rises more *-g-* than your hand moves down.

If we consider mechanical advantage, the forearm is a *-h-* machine; it does not enable us to make extremely strong movements. It has, however, *-i-* other advantages. It enables us, by a very small *-j-* of our *-k-*, to make:

(1) a quick sweeping movement,
or (2) if necessary, a careful delicate movement.

(advantage; amplify; coal; energy; expense; friction; fuels; heat; heavy; invented; less; machine; muscles; oil; opposite; quickly; work.)

A *-a-* worked by man can, at most, only do the same amount of *-b-* as the man does who is working the machine. Owing to *-c-*, some of the man's *-d-* is always changed into *-e-*, so that the work done by the machine is *-f-* than the work done by the operator. The *-g-* of using the machine is that it enables us to do the work more conveniently. When a weight is so *-h-* that it must be lifted a little at a time, it is convenient to amplify the force used; but it is convenient to do the *-i-* of this, when the work is so delicate that it must be done carefully. When the work is so urgent that it must be done *-j-* it is convenient to *-k-* the speed and distance of the operator's movement, even though this must be done at the *-l-* of the force used.

Much modern work requires heavy weights to be lifted quickly, and the energy of man's *-m-* is not then equal to the task. He has therefore *-n-* other machines which are driven by the energy obtained from *-o-* such as *-p-* and *-q-*.

CHAPTER V

Sensing

How our Brains get News from the Outside World.

We have learnt that food provides us with energy to move about. In making movements, we are often guided by what we see and hear, sometimes by what we taste, smell or feel. For example, we run to the footpath when we see an approaching car, or hear its warning hoot; we throw open the windows if we smell an escape of gas; we push away from us food which tastes bad; we flinch back from the oven door which feels hot, and we hold more tightly the plate which feels slippery. These ways of getting news about the outside world, we call Sensing. All living things, if they are to survive, must be able to get news in one or more of these ways. For ourselves, seeing and hearing are obviously very important kinds of sensing, and we will now consider what men of science can teach us about them.

Seeing: How Light brings us News.

We have already learnt that we depend upon sunlight for our food and for our health. Without sunlight, not only would our food supplies soon dwindle to nothing, but we should also fall a prey to many forms of disease.

Plants, as you know, cannot feed on the carbon dioxide of the air except in sunlight. They must have light, and it is interesting to notice the way they grow so as to get more and more. If trees are planted close together, they grow up straight and have very few branches on the lower part of the trunk. Many flowers, like the sunflower, will turn in order to face the sun. Others, like the daisy (day's eye), are so sensitive to sunlight that they open out in the daytime and close again at night. Our bodies, too, are affected by light, and sun-bathing is good for health, especially in the early morning before the sun's rays become too scorching.

Unlike plants, we and most other creatures have two special parts of our bodies which are extremely sensitive to light. Although it is very pleasant to feel the sun shining on our skin, you know how unpleasant it is to have to look right into the sun. You ought not to do so, for your eyes are very sensitive, and glaring sunlight is bad for them.

Many tiny insects have very good eyes, but some, which live entirely underground, are blind. Worms cannot see as we do; they have no well-developed eyes, but even they can tell the difference between dark and light. Eyes would be of no use to creatures which live in the dark, for it is impossible to see anything in perfect darkness. We sometimes say that cats can see in the dark. This is not strictly true as we shall learn presently. First of all, it is necessary to learn more about our own eyes.

60. Look in a mirror at one of your eyes. Sketch it in your notebook. Notice how well it is protected, not only by the eyelids, but also by the bony framework which surrounds it (forehead, nose, cheekbone).

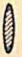
The most obvious use of the eyelids is to close over and protect the eye from glaring light. They also shut out light from the eye when we go to sleep. But the upper eyelid is working all day long although we are not always aware of it. Every few seconds, it flicks over the eye and washes its surface with a tear, which then flows away into the nose through a tiny hole. Watch whether other living creatures blink in this way.

The eyelashes are useful in helping to protect the eyes from dust and small insects. If a speck of dust or a fly should happen to get into your eye, you know how quickly the eye " waters ", as we say. This is Nature's way of washing the foreign substance away. Tears form so quickly that they cannot all flow away into the nose; they overflow and run down our cheeks. This is the best way of clearing your eye; the worst way, and one you should never use, is to rub your eye with your fingers.

Looking at your eye from the front, you can see three distinct parts—a white part, a coloured ring, and a black circle. The greater part of the eye you cannot see. It is shaped something like a ball. What we call " the white of the eye " is really an opaque covering which surrounds the eyeball just as the leather covering surrounds a football. At the front of the eye, this covering is hard and transparent, and if you look at someone's eye from the side, you will see that it bulges very like a bow-window. This bow-window is called the cornea. The coloured ring behind the window is an opaque curtain called the iris. The black circle is an opening called the pupil; it looks black because the inside of the eye is dark. What is the use of the iris? Try this experiment:

61. Look in a mirror in a fairly strong light. Cover one of your eyes with a dark cloth to shut out the light. Remove the cloth, quickly open your eye and watch the pupil in the mirror.

Just as you regulate the amount of light coming into a room by opening or drawing the curtains, so you do for your eye, but the curtain of the eye moves automatically. In strong light the iris closes in and the pupil is small; in the dark the iris draws back and the pupil is large. This is part of the secret why cats can see in the dark. Their pupils are so large in the dark that their eyes catch even the smallest amount of light. If it were perfectly dark, they could not see any more than we could. They would not, however, be so helpless as we should be in perfect darkness, because they are partly guided in their movements by their sensitive feelers. It would not matter much to a well-fed domestic cat if she could not see at night, but for her wild ancestors, who had to catch their food then, it may have been a matter of life or death.

The important parts of the eye, so far as we can see it from the outside, are these: the white; the cornea; the iris; the pupil. What is inside? Between the cornea and the back of the eye, the space is filled by three substances. They are, of course, all transparent. The most important of these is some hard jelly which, looked at sideways, is shaped like this:  It is called the lens, and is fixed just behind the pupil. In front of the lens, the space is filled with a salty liquid, and behind the lens, with soft jelly. The inside surface of the back of the eye is called the retina; it is covered with nerves which join up into a big cord called the optic nerve. This nerve connects the eye with the brain.

Notebook Exercises.—(*a*) Practise drawing this figure of an eye until you can do it from memory. Then draw it in your notebook and show the different parts, by writing the following letters in the proper places.

C—Cornea.
W—White of eye.
I—Iris.
P—Pupil.
R—Retina.
L—Lens.
O.N.—Optic nerve.

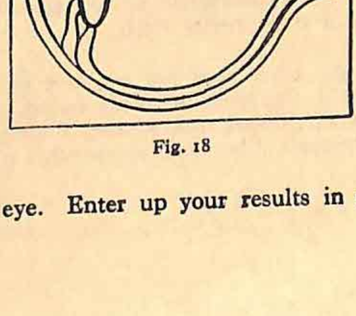


Fig. 18

(*b*) The eye is in some ways very like a camera but it is of course more wonderful and much more delicate than the best camera that man can make. Examine a camera, and find the parts of the camera which are like parts of the eye. Enter up your results in a table like this:

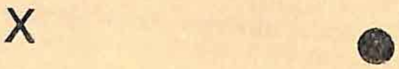
Eye	*Camera*
Retina	Photographic film

(*c*) Look at a picture on the ground-glass screen of a camera, and make rough sketches in your notebook to show the two chief ways in which the picture is different from the object.

What happens to Light inside the Eye?

When we turn our eyes to look at an object, for example, a book, a picture of the book is made on each retina. Messages immediately travel along the optic nerve to the brain, and by a mysterious process which even men of science do not fully understand, we know that the book is there in front of us. We say we see the book. We turn our head, and a different picture is formed on the retina; fresh messages go to the brain and we see the new scene. Try to imagine the hundreds of different pictures which are continually being thrown one after the other on to the tiny sensitive screens at the back of your eyes—still pictures and moving pictures; black and white pictures of printed pages, coloured pictures of ever-changing scenes. When you looked at the picture at the back of the camera, you noticed that it was upside down. The pictures on our retinas are also upside down, but our brain enables us to see the things the right way up. There is another interesting fact about our retina pictures; each one has a tiny flaw, because the spot where the optic nerve enters the eye is not sensitive to light. This spot is called the "blind spot". It is so tiny that we do not generally notice it is there. Here is an experiment which proves, however, that a blind spot does really exist:

62. Shut your left eye and fix the right eye on the cross. Hold the book at arm's length and then gradually bring it nearer, taking care to keep the right eye fixed on the cross all the time. You will find one place where the black dot disappears.



How we are able to see Moving Pictures.

After seeing a show at a cinema, have you ever wondered how it is possible for you to see things move on a screen which you know is quite still? It is easy to understand how you can see a thing really moving, for of course your retina pictures are changing all the time as you keep your eyes on the moving object. Hundreds of pictures are formed very rapidly one after the other on your retinas. Each picture is very slightly different from the one before it and the result is that you see the movement. A film photographer, using a special camera, does exactly the same kind of thing. He cannot take as many separate pictures as are made on your retina but he takes about 16 in a second. When these pictures are shown separately on the screen, one after the other at the same rate of 16 a second, they seem to run into one another. You then see the movement almost as well as if the real moving thing were there. You do not see sixteen separate pictures each second, because the effect of one picture has not gone before the message from the next picture arrives. You can now understand why, if a wheel is rotating fast, you do not see the separate spokes. Next time you are out, watch the spokes of revolving wheels. You can also experiment with chalk marks on spinning tops. You will find it interesting to examine a flicker, a little book of pictures which you flick over rapidly to produce one moving picture. You can make one for yourself by doing a series of sketches on different pieces of paper, each sketch showing the movement more nearly completed than the sketch in front.

Why we have Two Eyes.

63. Stand two pencils up on the table, one about 12 in. behind the other. Stand about 2 ft. away; keep the head still and look at the pencils, closing first one eye and then the other. What appears to happen?

Repeat the experiment, standing closer to the pencils, and note the difference in the result.

The above experiments show that each eye gets a different view, and that the nearer a thing is to the eyes the greater is this difference. In other words, the pictures formed on the retinas of two eyes looking at the same object are not exactly the same. But we see only one object. The messages from the two slightly different pictures reach the brain at the same time, and we see the two pictures as one. What is the use of having two eyes and getting two views of everything?

64. Examine a picture prepared for use in a stereoscope. Notice that it consists of two pictures. Are they exactly alike? They were taken at the same instant by a special camera with two lenses placed, as your eyes are, a little distance apart. Look at the picture in a stereoscope.

65. Place a matchbox on end about a foot from you in such a position that you can just see a little of the right-hand side of it. Close one eye at a time and notice what happens to your view of the box.

Experiment 64 suggests one reason why it is useful to have two eyes. We are better able to see things solid. Experiment 65 shows that when we look at a solid object each eye gets its own view. The two slightly different messages which our brain receives help our minds to get a true picture of the object we are looking at. We also find that having two eyes helps us very much in judging distances. It is not easy to pick up small things you reach out for, if you use one eye only. People who lose the sight of an eye have to learn how to judge distances with the one remaining eye. Here are two experiments on distance judging:

66. Place a pencil upright on the table about 18 in. away from you. Close one eye. Bring your hand sharply across in front of you and try to touch the pencil with the tip of your forefinger.

67. Make a dot on a piece of cardboard and stand the cardboard up at arm's length. Take a lead pencil in your hand, and shooting your hand out quickly, try to touch the dot with

the pencil point. Do this six times with the right eye closed. Measure the errors in millimetres and find the average.

Repeat the experiment first with both eyes open, and then with the left eye closed.

Two eyes also enable us to see on both sides of us without having to turn our heads. This was no doubt very useful to primitive men living among wild animals, and it is also useful to modern men living among fast-moving traffic.

68. Shut one eye, keeping the head still. Notice the difference in the breadth of view you get. Repeat the experiment, closing the other eye.

Why we cannot see in the Dark.

When we say we cannot see in the dark, it is only another way of saying that we cannot see unless there is light. Shut your eyes and you see nothing. Your eyelids are practically opaque, and they stop light from passing through your transparent eyes to the sensitive retinas behind. If no light falls on the retinas, no messages go from them to the brain. Without the messages you see nothing. The truth is that we only see when light enters our eyes. We can see the sun in the sky, or the flame of a lighted candle, because light comes from the sun or from the flame. This light enters our eyes, shines on the retinas, and starts messages travelling along the optic nerves to the brain. Then we see the sun or the candle. But how is it that we can also see things, like trees and people, which are not alight? The answer is that, although trees and people are not making light of their own like the sun and the lighted candle, they are in a sense alight. They are lit up by the light which falls on them from the sun or from some other source of light. Now light travels very fast. Men of science have measured its speed and found it to be 186,000 miles a second. This is nearly three million times as fast as the speed of the fastest aeroplane ever made, or twelve million times as fast as that of an express train. Some of the light falling on things at this tremendous speed bounces off again. We say that the light has been reflected, that is, thrown back. Light is all the time speeding along from the sun, striking against everything it meets, and bouncing off again. When you look at trees and people or at any opaque things, some of the light they are reflecting strikes your retinas and you see the things. In the dark, there is no light striking against things and therefore no light being reflected. That is why we cannot see in the dark.

Why we see some things easily.

Girls know how difficult it is to sew well, using black thread on black cloth. White things are easier to see than black, as you notice if you look round a fairly dark room. The reason is that white things reflect a good deal of the light which strikes them, while black things, on the other hand, absorb light and reflect very little. You can now explain why policemen on point duty wear white gloves and sleeves, and why the edges of station platforms are whitewashed. You can understand also why it is better to use dark coloured rather than white material as the lining for hoods of perambulators.

All opaque things, unless they are perfectly black, reflect light. Transparent substances, such as ice, clear glass, and water, allow light to pass right through them. That is, of course, why we can see things through the window; light comes from the things through the glass into our eyes.

We should remember, though, that nothing is perfectly transparent. Even clear water stops a little light, and if the water is deep, very little sunlight penetrates to the bottom. Divers can only see a few yards in front of them when they are 400 ft. down in the sea. Opaque things like brick walls stop all the light and the result is you cannot see things through them, no matter how bright the things on the other side may be. Even the light of the sun is cut off from us at night by the opaque earth, when in its daily rotation our side is turned away from the sun. But it is never perfectly dark even on the darkest night. Where does the light come from? We think at once of the moon and stars.

The Sky at Night.

If you look at the sky on a clear night you see hundreds of lights. The moon appears to be the largest and brightest. But, of all the shining things you can see in the sky, the moon is really one of the smallest. It looks large because it is the nearest, being only about 240,000 miles away. You probably think this is a very long way, but when you look up at the sky you must remember that some of the light which is entering your eye has travelled very much farther. A few calculations will help you to remember:

(*a*) We see the moon by sunlight which it reflects to our eyes. How long does this light take to travel from the moon to us?

(*b*) The nearest planet, Venus, is sometimes only about 27 million miles away. When we see Venus in the sky, we do so by reflected sunlight. How many minutes was it since this light left Venus?

(*c*) The sun is about 93 million miles away. If it is daytime, you are reading this book by light which has come from the sun and bounced off the book into your eyes. How long ago was it since this light started its journey?

(*d*) We see stars by starlight which they are making themselves. As we look at the nearest star, Proxima Centauri, about 25 billion miles away, light from it is entering our eyes. How long ago did this starlight leave the star?

If you have done your calculations correctly, you will have found that light takes about 1·3 sec. to reach us from the moon; about 2·4 min. from the nearest planet; about 8·3 min. from the sun; and about 4·3 years from the nearest star.

On a clear night, it is possible to see about 3000 stars with the naked eye. Photographs taken with the help of telescopes show that the total number is very much greater. It is in fact impossible to count them, but astronomers estimate that there must be thousands of millions. Every one of these stars is really a sun making its own light just as our sun does. In reality, many of these stars are far larger than our sun; they look small because they are so far away.

So great are the distances, that astronomers do not reckon them in millions of miles, but in light-years, that is, in the number of years it takes light to travel from the stars to our eyes. We have already calculated that, for the nearest star, this is 4·3 years. We may therefore say that its distance is 4·3 light-years. Reckoned in the same way, the distance of the Pole Star is 47 light-years.

In addition to the stars which make their own light, there are in the sky seven worlds like our own, revolving round our sun. They are called planets and have been named Mercury, Venus, Mars, Jupiter, Saturn, Uranus and Neptune. Like the earth on which we live, they are not alight, but they are lit up by the sun's light so that they shine in the sky. Some of them look brighter than the stars but that is because they are so much nearer to us. It is important to remember that compared with the stars they are really very small and they have no light of their own. In 1930, some astronomers reported that they thought they had discovered another planet still farther away than Neptune. This planet has now been proved to exist, and has been given the name of Pluto. The discoveries of the other two most distant planets, Uranus in 1781 by William Herschel, and Neptune in 1864 by a German astronomer, Galle, are stories which are full of interest.

In addition to the stars, planets and moons there are millions of nebulæ scattered about in space. These masses of cloudy luminous material are very far away (the nearest is about 850,000 light-years), but they are important, for it is from nebulæ that stars are made. According to Jeans, one of the greatest modern astronomers, each nebula contains enough stuff to make 2000 million stars.

We have already learnt that having two eyes helps us to see which things are near and which are far. The heavenly bodies are, however, too far away for our eyes to see them in perspective, and most people walk about under the night sky without realizing the grandeur of the scene all round them. You will find it very interesting to study the sky on clear evenings. Several newspapers print star maps every month. Cut one out, and with its help try to find some of the planets and prominent stars, and some of the important groups of stars called constellations. If you can get a pair of field-glasses, you will find additional interest in looking at the moon and the planets, especially Jupiter and Saturn.

We learn then that the things we see in the sky at night are of two kinds, like the things we see on the earth. Some, like the sun and stars, are alight and we see them by the light they are themselves making; others, like the moon and planets, are lit up and we see them by the light they reflect. The things we see on the earth are so close to us that the light from them takes practically no time to reach our eyes and so we see them as they are now. The things in the sky are so far away that light from them takes some time to reach our eyes, and so we see them as they were in the past. For example, the light from the French cliffs which can be seen at Folkestone takes less than $\frac{1}{9000}$th of a second to flash across the Channel. When, however, we see the moon, our nearest neighbour in the sky, the light from the moon has taken 1·3 sec. to get to us. That means we are seeing the moon as it was 1·3 sec. ago. When you look at the stars in the sky you are seeing them as they were years ago. The night sky is really giving you a glimpse backward in time. When you see the Pole Star next time, remember that you are seeing it as it was 47 years ago.

Books to Read.—The Romance of Modern Astronomy, H. Macpherson (Seeley, Service); *Stars shown to the Children*, E. Hawks (Jack); *Our World around us*, A. G. White (Watts).

Five-minute Lectures.—Books on astronomy will give you many ideas for interesting talks. Here are some suggestions:

(*a*) The sun, our fountain of light; (*b*) The moon, the orb of night; (*c*) The sun's family, the planets; (*d*) How stars are born; (*e*) How was the sun and planet family made?

Notebook Summary.

S. 1. SEEING

(books; bounces; enters; eyes; light; lit up; miles; moon; not; people; planets; reflected; second; see; stars; straight; sun; white-hot filaments; yellow flames.)

We only see things when light -1- our -2-.

Some things we see by the -3- they make themselves. Such things are: -4-, -5-, -6-, -7-.

Most things are -8- alight, but we -9- them because they are -10- by light coming from other sources. The light which falls on them -11- off again. Some of this -12- light enters our eyes and so we see the things. Some examples of things we see by reflected light are: -13-, -14-, -15-, -16-.

Light travels at a speed of about 186,000 -17- per -18-.

Notebook Exercises.—(*a*) Collect the necessary information and then enter up in your notebook a table of interesting facts about the planets. Like this:

Name of Planet	Diameter (in miles)	Distance from the Sun	Time taken to revolve round the Sun	Number of Moons

(*b*) What are the three chief uses of having two eyes?

(*c*) Write not more than six lines explaining why we cannot see in the dark.

Lights and Shadows.

Wherever you look you can see lights and shadows. Have you ever watched the dark shadows and the bright reflections as you walk up some dark stairs holding a flickering candle? The dark cinema is a good place to see lights and shadows; you have no doubt often looked at the straight beams going from the projector to the screen. Out of doors on a dark foggy night is perhaps the best place of all. If you come across a leafless tree near a street lamp, you then see, not only bright beams coming straight from the lamp, but also black masses of shade stretching straight away from the large branches, and ending in dark shadows on the road. Strange as it may sound, the best place to study light is in the dark. In broad daylight, there is so much light that we do not notice the striking contrasts between light and shade which we see at night or in a dark room.

We say we can see a beam of light in the cinema. You know, however, that we only see when there is something to reflect the light to our eyes. We see things; we cannot see light. In the cinema we do not see a beam of light; we see specks of dust and smoke lit up. These specks reflect the light to our eyes and show us where the beam of light is.

We say we can see a shadow of a branch on the road. We really see a part of the road reflecting less light than the other parts. This part looks dark and we call it a shadow. As you can see on a misty night, the shade is not only on the road; it is a dark space between the tree and the road. You can prove to yourself that shade fills the space behind an opaque object by a simple experiment:

69. Suspend an opaque object in front of a light, and notice where its shadow falls. Then place a sheet of white paper between the object and its shadow, and so find out where the shade really is.

The whole of space is filled with floods of light and masses of shade. If only we could distinguish all the various shades, what a patchwork design we should see! As we have said, we get a glimpse of what it is really like on a dark foggy night. Then the space all round us is seen to be filled with light and shade.

The sun, our chief source of light, is 866,000 miles in diameter. From this huge globe, floods of light start off in every direction, and light up even the farthest planet. There are also in space immense masses of shade trailing off behind each of the revolving planets. Sometimes the moon, in its journey round the earth, enters the earth's shade. Its light is then cut off from our eyes; we say the moon is eclipsed. In a similar way, the moon's shadow sometimes falls on the earth during the daytime and cuts off the sun's light. The stars become visible, birds go to roost, sensitive flowers close up. You can imagine how frightened our ancestors were when it became dark in the daytime during a total eclipse of the sun.

Notebook Summary.

S. 2. BLACK AND WHITE

(absorbs; appear; black; eyes; light; opaque;
reflect; shadow; very little.)

White things -1- most of the light which falls on them, but -2- things absorb it.

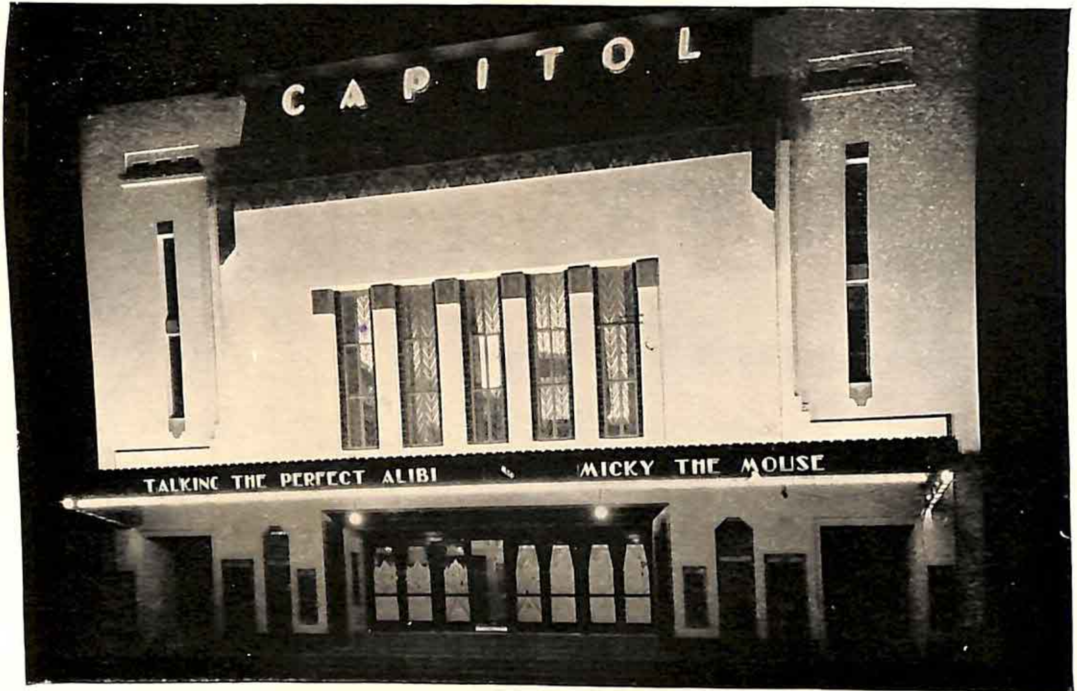
When things -3- black, it is because -4- light from them is entering our -5-.

The dark blackness may be caused by the -6- being absorbed. For example, the ink on a printed page -7- light and therefore looks black.

The dark blackness may be caused by the light being cut off by some -8- object. The -9- of my pen as I write is formed in this way.

Why we see ourselves in a Mirror.

You have probably noticed that in a room facing the sun, with the blinds drawn, splashes of sunlight are often to be seen on the floor or on the wall opposite the window. If you examine carefully, you will find



E 516

SIGNS AND FLOODLIGHTING AT THE CAPITOL KINEMA, EPSOM

Notice how light is reflected from the wall, and absorbed by the roof. Some parts of the building are in the shade.

Facing p. 88

that the sunlight is streaming in through small holes in the blind or perhaps in a ventilator. If there is any tobacco smoke in the room, or if the dust has been disturbed, you can see the paths of the beams of light. If you put a mirror in the path of one of the beams, one splash of light disappears. The light has been cut off by the opaque mirror. But, as you have often noticed when playing with a mirror, the light appears again somewhere else. By altering the position of the mirror, you can direct the spot of light to whatever part of the room you choose (see fig. 19).

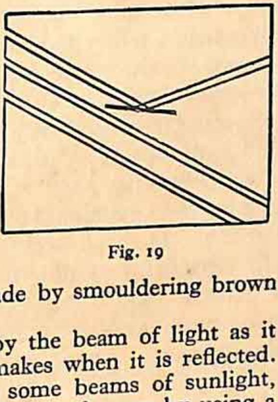


Fig. 19

70. Repeat the experiment described above. You will have to arrange the details to suit the room you are working in. The following hints may help you.

Choose a sunny day and a room facing the sun. Darken the room as much as possible. Pin up a piece of brown paper over one of the windows and in it make a few small holes with a pencil. A pocket mirror will do as a reflector; smoke can be made by smouldering brown paper.

Notice carefully the angle made by the beam of light as it strikes the mirror and the angle it makes when it is reflected.

If you cannot conveniently catch some beams of sunlight, you can make a beam of light in a darkened room by using a cylindrical electric torch. Unscrew the lens and with the help of some plasticene fasten it on the end of a cardboard tube. Put the lighted torch in the tube and move it to and fro until you get a clear beam.

A simple experiment which you can all do at home is the following:

71. Turn out the lights and put a lighted candle on the table. Hold a small mirror about six inches away so as to throw a reflection on the wall opposite. Then rotate the mirror slowly and watch the movement of the reflected light on the wall and ceiling.

Experiment 70 shows you that beams of light in the air are straight. Light travels in straight lines. That is why all the beams of light and masses of shade which you see have straight edges. It explains also why you cannot see round the corner of a building.

Experiments 70 and 71 show you that light bounces off a mirror in much the same way as a ball bounces off a smooth tennis court. If you throw a ball slantways at a smooth floor, it bounces off slantways; it comes off the floor at the same angle but in the opposite direction. If you want the ball to come straight up to you, it must hit the floor at right angles. If, however, you throw a ball at something very uneven, like stones on the seashore, you cannot tell where it will bounce. Half a dozen balls thrown in the same direction would be scattered in all directions. So it is with light. If rays from the sun bounce off your face and strike something not very smooth, such as a wall, the rays are scattered. If however, they strike a very smooth surface, such as the silvered back of a mirror you are looking at, the rays are not scattered (see fig. 20). They all bounce off together as a beam. If you are standing in front of the mirror, and looking straight at it, the light from your face comes straight back into your eyes, and you see what appears to be yourself in the mirror. These pictures seen in mirrors are called images.

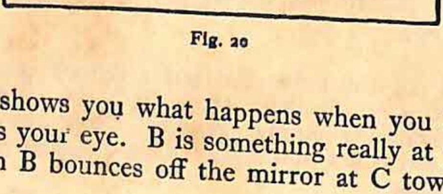


Fig. 20

Fig. 21 shows you what happens when you look sideways. A is your eye. B is something really at your side. Light from B bounces off the mirror at C towards your eye. Now, wherever things may really be, they always appear to be in the direction from which their light enters your eye. B therefore appears to be somewhere behind the mirror along the line AC.

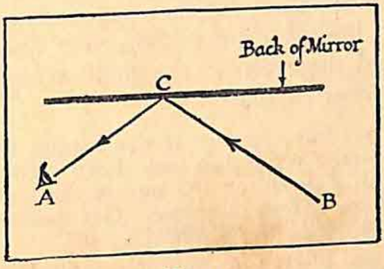


Fig. 21

72. Stand a large mirror upright. Walk in front of it from one side to the other. Notice where the things appear to be in the mirror and where they really are in the room. Remember that things always appear to be where their light is coming from, when it enters your eye.

73. Stand a small mirror upright on a piece of paper. (Plasticene makes a convenient stand.) Looking in the mirror, write your name and draw some designs on the paper. What do you find out about the distance of each part of the image behind the mirror?

74. Write your name in ink, and blot it. Look at the blotting paper in the mirror.

Discussions.—(*a*) Why can you see yourself in a mirror?

(*b*) Can you really see the black print of this book?

(*c*) Why do wet roads look shiny?

(*d*) Why do furniture and silver shine so brightly after they have been polished?

Notebook Summary.

S. 3. REFLECTION

(bounces; glossy paint; light; look; mirrors; not; polished surfaces; reflected; reflections; scatter; smooth.)

Light is -1- from most opaque things.

Those which are very -2-, like -3-, -4- and -5-, reflect light without scattering it. As a result they -6- shiny, and we can often see -7- in them.

Light is reflected from a mirror in the same way as a ball -8- off a smooth floor.

Many things are -9- smooth enough to appear shiny. They reflect -10-, but they -11- it in all directions.

Things are not always as you see them.

You have probably found out long ago that things are not always as they appear to be. When you first went to the swimming bath, you were perhaps surprised to find that even at the shallow end, the water was deeper than it looked.

75. Put a penny at the bottom of a deep glass jar. Pour in some water and look down vertically at the penny. Point with a pencil on the side of the jar where the penny appears to be. Mark the place. Get someone to pour in more water and notice the result.

76. Place a penny under a block of ice or glass and, looking down from above, point with a pencil to where the penny appears to be.

77. Put a penny in a basin on a table. Step back until you have just lost sight of the penny over the rim of the basin. Then stand perfectly still and get someone to pour water into the basin carefully, so as not to move the penny.

When, in experiments 75 and 77, water was poured on to the penny, it seemed to rise. In experiment 76, when you placed a block of ice or glass on the penny, it also seemed to rise nearer to you. And yet you know the penny did not move. Nor did you move. What did move? It was the beam of light which came from the penny to your eye. When light passes from glass, or ice, or water into air, it is moved out of the straight path along which it started to travel. This bending of light is called refraction. Men of science tell us that light does not travel quite as quickly through dense things as it does through air, and that this is the reason why it is refracted (i.e. bent).

There is one occasion when light is not bent on passing from one transparent substance into another. When it happens to strike the surface of the new substance exactly at right angles, its speed is changed but it goes straight on.

Notebook Exercise.—Describe experiment 77. The following notes will help you:

AN EXPERIMENT ON REFRACTION

(Book I, page 92)

(Air; appears; basin; beam; bent; did; entered; eye; I; light; not; penny; risen; saw; see; seem; straight; water; Water.)

-1- *in the basin.*—The beam of -2- from the penny travelled all the way in one -3- line. I was standing too far back for any light from the -4- to enter my -5-. Therefore I -6- -7- -8- the penny.

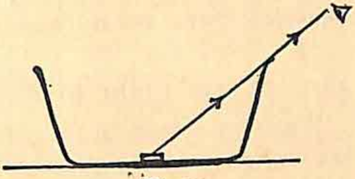


Fig. 22a

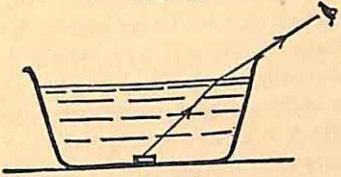


Fig. 22b

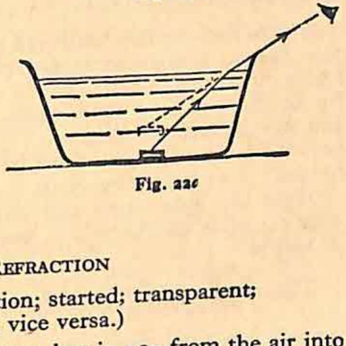


Fig. 22c

-9- *in the basin.* — The -10- of light from the penny was -11- when it passed from -12- to air. Some light from the penny now -13- my eye. Therefore I -14- the penny although neither -15-, nor the -16-, nor the penny had moved.

Why does the penny -17- to be higher?—When we see anything it -18- to be in the direction from which its light enters our eyes. Therefore when we see the penny, it appears to have -19- in the water.

Notebook Summary.

S. 4. REFRACTION

(bending; light; refraction; started; transparent; travelling; vice versa.)

Light passes through -1- things, but in -2- from the air into a denser substance, or -3-, the -4- is moved out of the straight path along which it -5- its journey. This -6- of light is called -7-.

Extra Experiments.—Here are three more experiments. The curious results you will observe are due to the refraction of light as it passes from air into water or from water into air.

78. Place a bowl so that a distinct shadow of the edge is thrown on the inside of the bowl. Stand back, and get someone to pour water into the bowl. Watch the shadow.

79 Draw a white horizontal line on some brown paper. Hold in front of it a medicine bottle filled with water so that you can see part of the line through the water. Hold the bottle and paper together at arm's length and watch the line as you raise and lower your arm.

80. Dip one end of a stick in water. What appears to have happened? What has happened?

How to use Light to make Pictures.

When you look at a photograph or a pen-and-ink sketch, you see the picture because some parts of the paper reflect more light than other parts. It is possible, as you see at the cinema or during a lantern lesson, to make pictures on a white background without making any marks at all. At first, the screen is lit up evenly; it reflects light evenly to your eyes and you see a white sheet. Then, by means of a lantern, light is thrown on the screen unevenly; it reflects this light and you see a black-and-white picture.

81. On a sunny day, darken a room as you did for experiment 70. Pin up a piece of brown paper in which you have made a tiny hole with a pin. Move a piece of white paper to and fro in the beam of light which comes through the hole. If you can get a piece of ground glass instead of the paper, it is better, for then the result can be seen by others who may stand behind, out of the way of the beam.

Make the hole larger and notice the result. Then place a burning glass in the beam, and move the screen to and fro as before.

The first time you see a bright little upside-down picture of an outside scene made by light coming through a tiny hole, it is very striking. In India, where they have very bright sunshine, it is not uncommon for such pictures to be made by the light shining through a chance hole

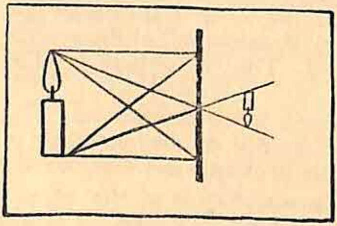


Fig. 23

in a blind. It is simply the result of light travelling in straight lines, as you will see by studying and discussing fig. 23.

The effect of making the hole larger is shown in fig. 24. So much light goes through in so many different directions that you simply get a flood of light.

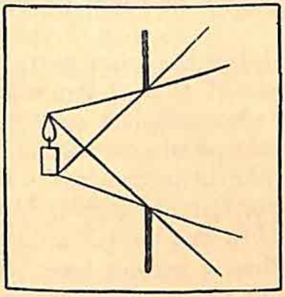


Fig. 24

If, however, we put in the large hole some glass shaped like a burning glass or like the lens in the eye, a very different result is obtained, as shown in fig. 25. Light, as you know, is bent when it passes from air into glass, and again when it leaves the glass. In fig. 25, you see how a lens bends the rays of light in towards each other, so that there is one place where they must come together again. If you put a white screen at this place, you see the picture clear and bright. We say the rays of light have been focussed. If the screen is placed nearer or farther away, the rays are mixed up and you see only a blurred picture.

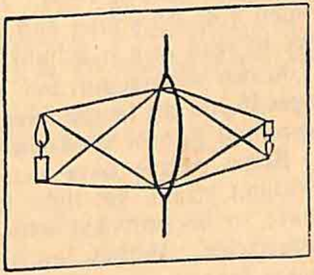


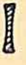
Fig. 25

82. Use a convex lens to focus the rays of the sun on a screen. Measure the distance of the centre of the lens from the screen.

The bright spot on the screen is a picture or image of the sun. Its position is called the focus of the lens and the distance of the focus from the lens is called the focal length.

83. Use the convex lens whose focal length you found in experiment 82. Stand it upright in a lump of plasticene. On one side place a lighted candle; on the other side place a screen. Arrange the distances of lens and screen so that you have a clear image of the candle on the screen. Move the candle farther away and find how you have to move the screen in order to keep the image in focus. Notice also how the size of the image changes.

In a camera, the screen is fixed, but the front part, in which the lens is set, can be moved to and fro until you have a clear picture. The photographer says, as he moves the lens, that he is getting the picture " in focus ". Our eyes are, as we have seen, like little cameras. In them, not only is the screen fixed, but the lens is also fixed. How then do we focus? How can we get a clear picture of a distant scene, and then a second later, an equally clear picture of a close-up view? The answer is that we do it by altering the shape of our eye lens. This lens is not made of hard glass, and we are provided with tiny muscles which enable us, without thinking, to make our lens flatter or rounder just as we need it in order to make a clear picture. It is very easy to strain the muscles of the eyes. You do so if your eyes are too near your reading book. It is very important, especially when you are young and your eyes are growing, not to try to read in a bad light, nor to read very small print. You can understand, too, what a strain there is on your eyes if you try to see things in a flickering light. A very common sign of eyestrain is headache.

Some people have defective eyes, and they cannot, without strain, get light focussed on the retina. They have to be provided with extra lenses in the shape of spectacles. If they are long sighted, it means that the light from a near object is focussed behind the retina, so that no clear pictures of such objects are easily obtained. It is only by straining, that the eye lens can be made round enough to focus the light farther forward. An extra lens of the same kind as the eye lens is required in the spectacles to help to bend the light in. This kind of lens is called a convex lens. If people are short-sighted, pictures are focussed in front of the retina and a spectacle lens is required to open out the rays of light a little. It is shaped like this , and is called a concave lens.

Discussions.—(*a*) Why are many modern electric lamps not made of clear glass?

(*b*) Notice all the different kinds of interior lighting arrangements you can (in shops, schools, and houses). Which are least likely to injure our eyes?

(*c*) Why are the headlights of a car on a dark road dangerous to people travelling in the opposite direction?

(*d*) Why should desks be placed so that windows are on the left-hand side of the writer?

Notebook Summary.

S. 5. LENSES

(air; bent; concave; in; lens.)

When a beam of light passes through a lens, the rays are -1- twice: (*a*) on passing from the air into the -2-, (*b*) on passing from the lens into the -3-.

A convex lens is often used to bend the rays -4- towards each other; a -5- lens is often used to bend the rays outwards from each other.

Notebook Exercise.—Describe experiment 83. Express the result like this (the initial letters of the missing words are given):

The f—— the object is from a convex lens, the n—— is the image, and the s—— does the image become.

Notebook Summary.

S. 6. FOCUSSING

(alter; far; focussing; large; lens; near; possible; retina; small.)

When using a camera or an eye, the object is some distance away, and the image is -1- and -2-. When using a magic lantern, the object is near and the image is -3- and -4- away.

Focussing is done by moving the -5- to and fro when using a camera or lantern. When using the eye, it is not -6- to move the position of the lens or of the -7-. The -8- is done by tiny muscles which -9- the focal length of the eye lens.

How light Pictures can be preserved.

The word " camera " is the Latin word for " a room ", and reminds us that the first cameras were simply darkened rooms (camera obscura) with sunlight shining through a tiny hole in the blind. Beautiful pictures were formed on the walls as in our experiment 81. It is not surprising that people who saw them were anxious to preserve them. The story of the early experiments to do so is too long to be told here. It is of course the story of the invention of photography. To cut a long story short, it is possible to take photographs because early experimenters discovered that some salts were very sensitive to light. The most sensitive are salts made from silver, and it is silver salts which are used in the making of photographic films, plates, and printing paper.

84. Soak a filter paper in a solution of silver nitrate. Put it in a sunny place.

85. Examine a piece of photographic printing-out paper. The glossy surface contains a thin coating of a silver salt. Put the paper in a sunny place, and on it put some opaque things, such as a key and a pencil.

86. Use a printing frame, and make pictures of (*a*) a leaf (*b*) a piece of lace on some printing paper.

87. Examine a photographic negative. Use it to print off a picture.

The results of experiments 84–87 are all due to the influence of sunlight on silver salts. The pictures so made are not permanent because if more light falls on the silver salt, it will all turn dark. It is necessary therefore to wash away the unchanged salt. This process is called " fixing " the picture, and is usually done by washing the print in a solution of another salt called hypo.

The film used in the camera is a roll of celluloid with a thin coating of a paste containing a silver salt which is very sensitive to light. The picture formed by the camera lens is allowed to rest on this film for a very short time. Now this picture is really made by light of many different degrees of brightness, and this light affects the silver salt. If, however, you looked at a film which had been exposed to light in this way, you would not notice that anything had happened. The change begun by the light has to be finished by dipping the film in some chemicals. This is called developing the film. It then has to be fixed in the same way as the pictures printed on the paper. Where the light was brightest, the silver salt was most changed and so on. The result is that, as you will have noticed, the picture made on the photographic film is black where it ought to be white and vice versa. This is why it is called a negative; it reflects light to the eye in just the opposite way to that in which the real picture does.

Discussion.—Why does the picture on the film come out "negative" and the picture on the printing paper come out "positive?"

Photography has greatly increased our powers of seeing. By taking long exposure photographs, stars have been discovered which are invisible to the eye even when looking through powerful telescopes. Photographs of tiny creatures under the microscope enable us to study them far better than would be possible if we had to depend only on the memory of our own retina pictures. Photographs of a piece of country taken from an aeroplane reveal information which could not be seen by anyone on the ground, and which no observer would be able to see with his eye, merely by looking over the side of the plane.

Black-and-white photography is about 100 years old. Attempts are now being made to preserve *coloured* pictures made by light. Some coloured photographs were reproduced in 1932 in the Weekly Edition of *The Times* newspaper, and before long we shall probably see coloured pictures in our daily papers. How is it that we are able to see things in colour as well as in light and shade? This question we shall try to answer in Book II.

Notebook Summary.

S. 7. PHOTOGRAPHS

(brighter; changed; dark; developed; fixed; light; photograph; positive; print; salt; sensitive; silver; solution; unaltered.)

Plants and animals are -1- to sunlight; so also are some salts, especially salts made from -2-.

When we take a -3-, we expose a silver -4- to -5-. The action of the light is completed by chemicals when the film is -6-. The -7- salt is washed away by a -8- of hypo when the film is -9-.

The -10- the light, the more the silver salt is -11-. This is why the bright parts of a picture look -12- on a negative.

When a -13- is made, very little light can get through the dark parts of the negative; the result is that a -14- picture is made.

Books to Read.—*How Photography came about*, Gibson (Rambles in Science: Blackie); *The Mysterious Ocean of Æther*, Gibson (Rambles in Science: Blackie); *The Romance of Modern Photography*, Gibson (Seeley Service).

Five-minute Lectures.—The books mentioned above will help you to prepare talks on the following subjects: (*a*) Early English experiments in photography; (*b*) Early French experiments in photography; (*c*) Cinema photography; (*d*) How photographs are printed in books; (*e*) Optical illusions.

Other subjects to choose from: (*f*) The care of the eyes. (*g*) How to take good photographs. (*h*) How to make a pin-hole camera. (*i*) How to make a periscope. (*j*) How the magic lantern works. (*k*) How a daylight advertising sign works. (*l*) How to make the best use of sunlight for health.

Hearing: How Sound brings us News.

Keep as still as you can for a few moments and listen. What a variety of sounds you hear! As I write, I hear the sounds of people walking, the humming of a motor, the whistle of a steam engine, the rustling of paper, the moaning of the wind, and the striking of a clock. It is almost impossible to get away from sounds; some are loud, some soft; some are high and shrill, others low and deep; some sounds are noisy, others are musical. Even if you put your hands over your ears, it is difficult to shut out every sound. What causes sounds and how do we hear them?

As you listen, think what is happening at the various places where sounds are being made. A man is walking about; a motor engine is revolving; steam is rushing through a whistle, and so on. Every sound comes from a place where something is moving. This is the secret of sound—movement. Nothing which is perfectly still can make a sound.

But how is it that you can hear sounds at some distance from the place where they are made?

88. Suspend an electric bell in the receiver of an air-pump. Set the bell ringing and extract the air from the jar.

If you have no air pump, here is a similar experiment, though not such an effective one:

89. Suspend a small bell B in a flask, fitted up as shown in fig. 26. Open the clip C on the rubber tubing and drive the air out of the flask by boiling the water. Remove the flask from the bunsen burner, at the same time closing the clip to prevent air rushing in again. Cool the flask and notice how the bell sounds now, when you shake the flask.

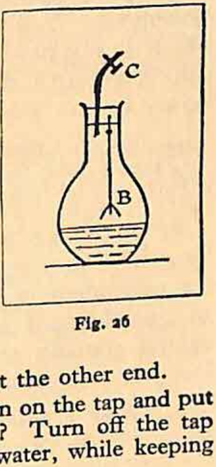


Fig. 26

90. Get someone to scratch one end of a long wooden pole with a pin, while you listen with your ear against the other end.

91. Find an iron railing about 600 ft. long. Put your ear against the railing and get your partner to tap the railing at the other end.

92. Next time you are having a bath, turn on the tap and put one ear under water. What do you hear? Turn off the tap and drop a coin or small stone into the water, while keeping your ear under the surface.

We learned earlier in this chapter that light can travel through airless space. Experiments 88 and 89 show us that sound cannot travel in this way. It seems to need something to carry it. Air is the carrier of most of the sounds we hear, but as we find in experiments 90–92, wood, iron, and water will also carry sounds. As a matter of fact, sound will travel through anything—solid, liquid, or gas.

In experiment 91, you heard two taps one after the other. This is because sound travels more quickly through iron than it does through air. Its speed in air is about 1100 ft. per second, very much less than the speed of light. This is why you do not hear the clap of thunder until some time after you have seen the flash of lightning. For the same reason, if you are watching a cricket match from a distance, you see the ball travel some way from the bat before you hear the sound of the hit.

How Sound is made.

We have noticed that sound seems to be made by movement. You can, however, make many movements which do not produce sound, as for example, if you move your finger up and down, or if you swing a piece of string slowly to and fro. Now do the following experiments:

93. Stretch a piece of string or elastic and pluck it.

Clamp a long ruler or thin piece of steel in a vice, bend it back and let it go.

From these experiments it seems as if sound is made by things moving rapidly to and fro. A rapid to and fro movement is called vibration. Many things vibrate so quickly, and move such a short distance, that you cannot actually see they are moving at all. There are however some better ways of finding if things are vibrating.

94. Make a note by striking the prongs of a fork on the table; immediately touch your tongue lightly with them.

Strike them again, holding the handle loosely between your thumb and finger.

95. Strike a tuning fork, and touch one prong against a tiny piece of cork suspended by a thread.

96. Set a bell ringing and touch a ping-pong ball with it.

When things vibrate in air, they start the air vibrating.

You see a large slow-motion model of what happens, when you watch a goods train shunt back and then stop suddenly. The first wagon moves back, pushes the second which pushes the third, and so on. We say that a wave of movement passes along the train. The engine stops and another wave is formed. When a bell rings, the same kind of thing happens to the air. The short, quick, to and fro movements of the metal start the air trembling or vibrating; we say that waves of movement start off in all directions in the air. Whenever you hear a sound of any kind, you can be quite sure that some vibrating thing must have started the air vibrating. This is true whether the sound is the squeaking of a rusty hinge or a beautiful note from a good voice. As you listen to the multitude of sounds all round you, try to imagine what a commotion the air must be in. Air vibrations, or as we call them, sound waves, are travelling out in all directions from dozens of vibrating objects. When these air vibrations reach our ears, we hear sounds.

How we hear Sounds.

You have all seen a dog prick his ears when some suspicious sound puts him on the alert. He is moving his ear trumpets so as to catch the sound waves better. We have ear trumpets too, but few human beings now can move them. Men of science tell us that long ago, our ancestors could move their ear trumpets but gradually they found that, for various reasons, it was not necessary to do so. As a result, man lost little by little the power he once had. Our fixed ear trumpets are still very useful for catching sound waves, though they are probably not so efficient as the movable ear trumpets of some other living creatures.

We cannot find out much about our ears by looking at them, but they are such a wonderful part of our living machinery that you ought to know something about what is inside. Fig. 27 shows you the most important parts of the ear.

The ear trumpet leads into a small passage about an inch long. This is kept clean by a supply of wax which is made on the sides of the passage. This wax gradually works its way out, bringing with it any dirt or dust which may have blown in.

The far end of the passage is closed by a thin skin D, stretched tightly across it; this is called the ear-drum. The middle part of the ear contains three tiny bones called the hammer H, the anvil A, and the stirrup S.

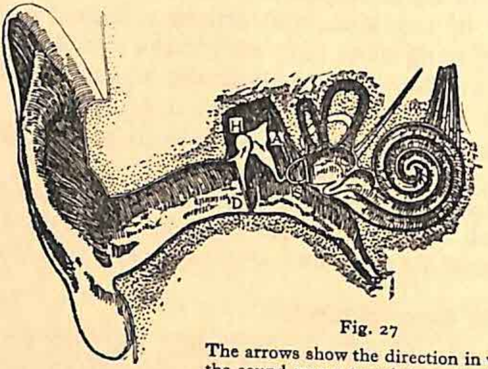


Fig. 27

The arrows show the direction in which the sound waves travel through the ear

This part of the ear is joined to the throat and mouth by an open tube E. The middle ear is therefore always filled with air. The curiously shaped inner ear is filled with liquid. The coiled part is connected to the brain by nerves.

When you hear a sound, the vibrations of the air, caught by your ear trumpet, pound upon the ear-drum and cause it to vibrate. These vibrations are passed on through the middle ear to the liquid in the inner ear. The nerves pick up the vibrations here, and pass messages on to your brain. You then hear the sound. Of course it is all done very quickly, the messages reaching your brain in a very small fraction of a second after the sound wave reached your ear-drum.

The ear is a very wonderful and delicate receiving set, and you ought to take great care that no harm comes to it. You should never poke things into your ear, or "box" anyone's ears, for it is quite possible by either of these means, to injure the drum and make the ear deaf. Another source of harm is the nose and throat, for, as we have seen, the middle ear is open to them. This is why bad colds affect our hearing. It also reminds us how necessary it is to keep the nose and throat healthy.

Discussions.—(*a*) Do all sounds travel at the same rate under the same conditions?

(*b*) What causes the "buzz" of a fly?

(*c*) The timekeeper at a sports meeting does not rely upon hearing the report of the starter's pistol. Why not?

Notebook Summary.

S. 8. HEARING

(carriers; ears; feet; hear; iron; movement; second;
Vibrating; vibrations; water; wood.)

We only hear sounds when there is -1-. -2- things cause the air around them to start vibrating. These -3- pass through the air and some of them enter our -4-. We then -5- sounds. Many solids such as -6-, and -7-, and liquids such as -8- are also good -9- of sound. The speed of sound in air is about 1100 -10- per -11-.

How to make Sounds louder.

How do you make loud sounds? You shout, you blow a whistle as hard as you can, you bang the drum. In other words, you can increase the loudness of the sound you make by increasing the amount of energy you expend. The following experiment shows you what happens:

97. Pluck the open G string of a violin, gently at first and then harder. Notice how far the string moves from side to side and notice the kinds of sounds you hear. (A good way of seeing the extent of the vibrations of the string is to place on it a small piece of paper folded like this, Λ.)

You learn from this experiment that you hear the loudest sounds when the vibrating string makes the biggest to and fro movements. The greater these are, the more violently is the air disturbed and the louder is the sound you hear. We say the loudness of the sound depends upon the extent of the vibrations. As sounds travel, the extent of the vibrations get less and less. The farther they go from their source, the greater will be the amount of air disturbed. Some of the energy is used up in this way, while some is required to overcome the friction of the air. This explains why sounds get fainter, the farther they travel from the vibrating object.

98. In a quiet room get someone to move a watch slowly away from you to one side keeping it level with your ear. Raise your hand as soon as you can no longer hear the tick. The distance of the watch is a rough measure of the keenness of your hearing.

Test the hearing of your other ear in the same way.

Compare by this method, the keenness of your hearing with that of other people.

Sometimes you make sounds louder by using a larger vibrating object. A louder sound comes when you beat the big drum than when you strike the kettle drum with equal force. But you have probably noticed that some of the sounds we hear quite easily, come, in the first place, from vibrating things with very small surfaces. A violin string, the disc of a loud speaker, and the gramophone needle are examples of things of this kind. A gramophone needle could by itself set up only very small air vibrations. If we had no means of increasing, or, as we say, amplifying them, we should be unable to detect them even a short distance away.

99. Strike a tuning fork and hold the end on the lid of an empty wooden box. Compare the loudness of the sounds you hear when the fork is held first away from the box, then touching it.

The sound you heard was increased when the fork touched the box lid. The vibrating fork caused the wooden box lid to begin vibrating as well. These vibrations caused more air, inside and outside the box, to start vibrating; the result is that the sound which the fork produced is amplified. You can now understand one important use of the body of a violin, the box of a gramophone, and the case of a piano. They amplify the sound by increasing the size of the vibrations.

Another way of amplifying sounds is shown by the following experiment:

100. Hold a vibrating tuning fork over a tall gas jar. Carefully and slowly pour water into the jar until you find that the column of air seems to swell the note of the tuning fork.

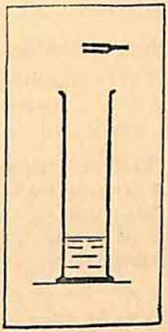


Fig. 28

In this experiment the column of air acted very much in the same way as the box did with the tuning fork. It began vibrating itself and the note it gave out, being the same as that of the fork, added to the sound you heard. We say it resounded to the note of the fork.

Amplified sounds are often less pleasant than the original sounds. Makers of musical instruments do all they can to reduce this defect. The quality, as it is called, of the sounds produced, depends upon the shape, material and size of all the vibrating parts. If you strike a note upon the piano, and then sing exactly the same note yourself, anyone can distinguish the two sounds for they are different in quality. The piano note is a mingling of the vibrations of the strings, of the sound board, of the air within the body, and of the case of the instrument itself. The quality of the note you sing depends upon vibrations of your vocal cords (pieces of tough membrane inside your Adam's apple), and also upon other vibrations in your throat, mouth, and the cavities of your head.

Discussions.—(*a*) Why do sounds carry better on a foggy day than on a sunny day?

(*b*) Why do we usually hear the big drum of an approaching band before we hear the other instruments?

(*c*) How does a megaphone help the voice to carry?

(*d*) How do ear trumpets assist partially deaf people to hear?

(*e*) How does a violinist make loud and soft notes?

Notebook Summaries.

(amplify; extent; fainter; farther; hear; louder;
material; pass on; shape; size; vibrations.)

S. 9. Loud and Soft Sounds

The -1- we are away from a vibrating thing, the -2- are the sounds we -3-.

We hear -4- sounds from the same source when the -5- are of greater -6-. We can also -7- sounds by causing the vibrating object to -8- vibrations to other things.

S. 10. Quality of Sounds

The quality of the sounds we hear depends upon the -9-, -10-, and -11- of the vibrating source.

Notebook Exercise.—Explain why a note played on a cornet sounds different from the same note played on a violin.

High and Low Sounds.

When listening to a violinist, have you ever wondered how he is able to make such a variety of sounds? He can play notes which are very low for you to sing, and notes which are as high as those in a bird's song. This difference between high and low sounds is known as a difference in their pitch.

101. Turn one of the pegs of a violin until the string is quite loose. Slowly tighten it up—this is known as increasing the tension in it—and keep plucking the string. What is the effect on the pitch of the notes produced?

This experiment shows you that the tighter you make the string, the higher will be the pitch of the note which it will produce. One of the first things a violinist does, when he is preparing to play, is to get his strings at the right tension. He tunes up his violin so that each of the four strings gives out the note he wants. The piano tuner works in the same way. If the piano is to be in tune, the tightness of each string must be so adjusted that it will vibrate a particular number of times each second. When you strike the middle C of a piano, the note you hear comes from a string which vibrates about 260 times each second. If the tension in this string were increased, it would make a greater number of vibrations each second, and the pitch of the note would be raised.

Look inside a piano, and you will see that there are scores of strings. The violinist, however, has only four strings. How does he get all the notes he wants?

102. Pluck the open G string of a violin, and place your finger very lightly on any part of it. What do you feel?

Place your finger firmly on the string, an inch or so from the head of the violin, and press it hard against the neck of the instrument. Pluck the string and find which part is now vibrating.

103. Use the violin to find how the pitch of the note alters as you shorten or lengthen the vibrating portion of one of the strings.

Experiment 103 explains what the violinist is doing when you see him moving his fingers from place to place on the strings. He is merely altering the lengths of the vibrating portions. The shorter a string is made, the more vibrations it makes each second, and therefore the higher the pitch of the note produced.

This is also true of vibrating columns of air. In experiment 100, you poured water into the gas jar until you got a column of air of such a length that it would vibrate at the same rate as the tuning fork.

104. Repeat experiment 100 with tuning forks of different pitch. Find how the length of the column of air alters with the pitch of the forks you use.

105. Place a tube in water as in fig. 29, and make the column of air vibrate by blowing across the top of it. Alter the length of the column by raising or lowering the tube in the water. Find how the pitch of the note alters.

If you look inside a large organ, you will find that the long pipes are the ones which produce the deep bass notes, while the shorter pipes give out the high notes.

You may also notice that some pipes are wider than others. Some organ pipes are made of wood, some of metal; some are square, others are round. These variations are made in order to produce different qualities in the notes given out. Pipes which are wide in proportion to their length give a powerful note, while narrow pipes give soft sweet notes. You have probably often noticed what a great many different effects an organist can obtain from his instrument.

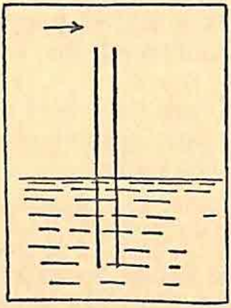


Fig. 29.

If you start a humming top spinning at full speed, at first you hear no note at all. When the speed has decreased a little, you hear a note. The pitch of this note gets lower and lower as the speed of the top decreases. Then, just before the top falls over, the note fades away altogether. This illustrates the fact that our ears are only tuned to pick up certain vibrations. As a matter of fact, these vibrations must be not less than about 50, and not more than about 23,000 per second. Human beings are different from some other living creatures in this respect. Dogs, for example, have been trained to answer to whistles which give out vibrations of such high frequency that no human ear could pick them up.

Notebook Summary.

S. 11. HIGH AND LOW SOUNDS

(air; less; long; lower; more; pitched; second; short; thin; tightly; vibrating; vibrations.)

We hear high -1- sounds when things are vibrating many times a second, e.g. a -2- stretched, -3-, -4- violin string.

We hear -5- pitched sounds when things are -6- fewer times a second, e.g. a wide, -7- column of -8- in an organ pipe.

We are only able to hear sounds when the –9– are –10– than 50 and –11– than 23,000 per –12–.

Summarize what you have learnt about the pitch of vibrating violin strings. Like this:

THE VIOLIN: HIGH AND LOW NOTES

(Book I, pages 108–110)

Violin String		Pitch of Note	Speed of Vibrations
Tension	increased decreased	high low	increased decreased
Length	long short		
Thickness	thin thick		

Sounds we do not Like to Hear.

We saw in Chapter IV, how, by the invention of machinery, men of science have helped us to move ourselves and heavy things about quickly. This is very convenient, for it helps us to get a great deal of work done. There is, however, one serious disadvantage. Fast moving machinery makes a great deal of sound, and unlike most of the sound we have been making in our experiments, it is often unpleasant and tiring to listen to. We call it noise. It is impossible to say exactly what is the difference between music and noise, for what is music to some people, others would call noise. The chief difference is that musical notes are made by regular vibrations while noisy sounds are made by irregular vibrations. It is something like the difference between travelling in a car which has pneumatic tyres and good springs, and travelling in a cart which has iron tyres and no springs. In one case, you sway with a pleasant regular rhythm; in the other, you are jolted about unpleasantly

By disturbing the regular vibrations of a violin string, you can change a pleasant note into a jarring noise. Try this experiment:

106. Hold a pen nib so that it just touches the vibrating string of a violin.

Another kind of unpleasant sound is produced by very loud musical notes. If you were to place your ear close to the trumpet of a cornet which was being played, the very loudness of the note would make it sound unpleasant; indeed, the air vibrations would pound upon your ear-drum with such force that the effect might even be painful.

Men of science are continually making experiments to find ways of reducing noise and of shutting it out from buildings. It is very necessary to take extra precautions to deaden sound in those modern buildings which have a steel framework, for steel is a very good carrier of sound. In many buildings special sound-resisting plaster is used, and the space under the floor boards is often loosely packed with material which is not easily set vibrating. Dried seaweed, fibres of various kinds, and asbestos have been found useful for this purpose.

Notebook Exercises.—Add examples to the following lists:

1. *Modern Inventions*

(a) *Which increase the amount of noise in the world*	(b) *Which decrease the amount of noise in the world*
Pneumatic drills.	Pneumatic tyres. Rubber roads.

2. *Things we can do to lessen noise in School and Home*

Oil hinges.

Sounds which come back.

If you call out your name in a large empty building, you can sometimes hear it repeated as if someone were mimicking you. Some railway arches will return sounds quite distinctly. In hilly countries, echoes, as they are called, are quite common. The sound comes back just as light does when it strikes a reflector. The following experiment shows you that sound can be reflected:

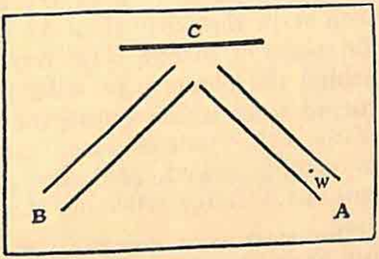


Fig. 30

107. Arrange two cardboard or metal tubes about 2 ft. long as shown in fig. 30. In the end of A get your partner to hold a watch W. Place your ear at B and listen carefully to the ticking of the watch. Now get your partner to place a large shiny piece of metal at C. What effect has this upon the sound you hear?

Get your partner to whisper to you through A with and without the metal sheet C. Notice the difference between what you hear at B each time.

Try the effect of substituting a piece of rough cloth for the metal sheet C.

If sound waves are reflected in this way, why do you not hear echoes everywhere? The reason is that these sound messages, like the light messages from the pictures on cinema films, run together if they reach the brain very quickly one after the other. The result is that we then hear one sound only. Whenever you speak in a room, your words are always echoed back, but if the echo reaches your ear less than $\frac{1}{10}$th of a second after you speak, you are unable to distinguish it; the echo merely amplifies for you the sound you made. This is why your voice often sounds so powerful when you sing in a small room like a bathroom.

In a large hall, where the walls are a long way from the speaker, echoes sometimes produce an irritating effect, as they confuse the hearers by coming a fraction of a second after the original sounds. Small as this interval of time is, it is sufficient for the sound to be noticed, and the result is something like this: " Second-ond ".

In modern buildings, such as concert halls and talking picture theatres, engineers make a special study of sound reflections. They try to make use of them in such ways that they improve rather than interfere with the music or speech. One way of doing this, is to place, behind the platform or talking apparatus, a recess with curved sides which reflect the vibrations into the body of the hall. Echoes which cannot be used in this way to amplify sound, are often toned down by hanging curtains over the reflecting surfaces.

Discussions.—(*a*) Imagine yourself sitting at the back of a hall listening to a speaker. Would you hear more distinctly if the hall were full of people or if it were empty?

(*b*) If you stand 500 ft. from the face of a cliff and shout "Ho!" when will you hear the echo?

How near to the cliff can you walk, and still hear an echo when you shout?

Notebook Summaries.

S. 12. NOISE

(irregularly; loud; noises; unpleasant.)

Sounds which are -1- to us we call noises. Some -2- come from objects which are vibrating -3-. An extremely -4- sound is unpleasant to most listeners.

S. 13. ECHOES

(echo; reflected; Sound; surfaces.)

-1-, like light, is -2- by smooth -3-. The reflected sound is known as an -4-.

Notebook Exercise.—Write an account of experiment 107.

Book to Read.—*Telephones and Gramophones*, Gibson (Blackie). Chapters X, XI, and XII.

Five-minute Lectures.—Prepare talks on some of the following subjects:

(*a*) The gramophone. (*b*) The human voice. (*c*) Musical instruments. (*d*) The speaking tube. (*e*) The songs of the birds. (*f*) Care of the ears. (*g*) How to make a string telephone. *h*) The original meanings of important words in Chapter V, e.g. gramophone, megaphone, piano, photograph, astronomer, optic. (Look them up in an etymological dictionary.)

CHAPTER VI

How Much Have You Learnt?

Try to read the following paragraphs, filling in the right words. Most of the blanks can be filled by single words, but some of them need a short phrase. If you cannot find the right word for any blank, read on, for you may get a hint from the next sentence. Try to fill each blank before seeking help. If you really need help, try to help yourself by reading up the subject, either in this book or in your notebook. Check your results by the answers given on p. 120.

A HUNDRED QUESTIONS

All -1- things, both -2- and animals, must -3- and feed. Plants get their -4- from the earth and the -5-. Animals depend on -6- for their food. Some of this food supplies them with -7- which is used by muscles to make movements. In making -8-, animals are -9- by the news of the outside world which their brains get in various ways, called -10-. Five kinds of sensing are: -11-, -12-, smelling, tasting, and feeling.

We breathe in through -13-; plants breathe through -14-; fish breathe by means of -15-. The air breathed out contains -16- carbon dioxide than the air breathed in. -17- is the gas made when carbon -18-; it is -19- than air; it -20- flames.

In addition to water, we -21- the following kinds of foodstuffs:

Energy-giving foods	*-25- foods*	*Health-giving foods*
-22-	protein	-26-
-23-		-27-
-24-		

Plants feed on the -28- -29- of the earth. In -30-, they also feed on the -31- which is in the air. They make -32- out of carbon dioxide and -33-. The starch is changed into -34- which is -35- in water. In the form of -36-, sugar is carried to all parts of the plant. The sugar, which is not wanted for growth, is -37-, in the form of -38- (as in the sugar cane), or in the form of -39- (as in the potato); or in the form of -40- (as in the fruit of the olive tree).

The -41- they obtain from food, animals use when they move. Their movements are made by -42-, -43- and relaxing.

Whenever anything is moved, some -44- is done. When we do work, we must exert -45-, and to exert force, we need -46-.

There are other -47- in the world besides those we can exert by means of our muscles, e.g.:

(*a*) The downward -48- which the earth exerts on every object; it is called the -49-.

(*b*) The "pull" away from the centre which whirling objects seem to exert; it is called -50-.

(*c*) The force which has to be overcome when one object is made to slide over another; it is called -51-.

Most of our muscles are attached to -52- which work as levers. A lever can be turned round its -53- by means of force. The turning effect of the force is called the -54- of the force. It is measured by multiplying the -55- by its -56-. A lever will balance when the moments in one direction -57- the moments in the opposite direction.

The point through which the weight of an object may be considered to act is called its -58-. If the -59- line through the centre of gravity comes -60- the base of an object, this object will fall over.

Many machines enable us to move heavy weights by small forces. Such machines are said to have a -61- advantage. Other machines, like levers of the -62- class, never enable us to do this. They are used to gain either -63- or delicacy of movement.

We see when -64- enters our eyes, falls on the -65-, and messages travel along the -66- nerves to our brains. The amount of light entering the eye is regulated by the -67-.

White things -68- most of the light which falls on them; black things -69- it.

Light travels in -70- lines. It is reflected from -71- surfaces without being scattered. When light passes through one -72- substance into another, it is -73-. The convex -74- in the eye bends the rays of light inwards, and -75- them on the retina. Then we see clearly. Long sight is corrected by spectacles containing -76- lenses; short sight by spectacles containing -77- lenses.

When we take photographs, we make use of -78- salts which are sensitive to light.

We hear when -79- of the air fall upon our -80-, and messages travel to our brains. If the vibrations are -81-, the sounds are generally pleasant; if they are irregular, we hear -82-. The greater the extent of these vibrations, the -83- is the sound. The greater the number of vibrations per second, the -84- is the pitch of the note we hear. The rate of vibration of a string can be increased by -85- the string, by using a -86- string, or by -87- the tension in it.

Now try to answer these questions:

88. What percentage of carbon dioxide is there in fresh air?

89. What percentage of carbon dioxide is there in the air we breathe out?

90. How high is the atmosphere?

91. What liquid is used when testing for carbon dioxide?

92. What do the bubbles in boiling water consist of?

93. What does the ash left after burning wood consist of?

94. What liquid is used when testing for starch?

95. What is the name of the unit used for measuring work?

96. What is the name of the opening through which light enters the eye?

97. How fast does light travel?

98. How far away is the sun?

99. What is the middle ear filled with?

100. How fast does sound travel in air?

A Novel way of observing the World around us.

Here is an amusing way of testing how much science you have learnt. It may also reveal to you how much more is yet to be learnt.

Pretend to put on a patent headgear, which makes you observe only the scientific facts all around you. Equipped with this imaginary apparatus, try to describe your surroundings. The following introductions may help you:

" Everywhere, people are moving their limbs, their muscles contracting and relaxing, and using up the energy they have obtained from starch, sugars and fats eaten at recent meals A boy steps on a piece of orange peel. . . ."

" The costers' barrows are laden with food. Here are oranges containing salts extracted from the soil of Spain. . . ."

" The noise is deafening. Air vibrations are pounding upon the ear-drums. . . ."

" There is a man digging up the road. Pressing down with his right hand, he is now using his spade as a lever of the first class. . . ."

" A cloud passes between us and the sun. . . ."

Science and Health.

Make a rough summary on scrap paper of all the health lessons you have learnt from this book. Then use the index to correct and amplify your summary. Make a fair copy in your notebook.

The Index and How to Use It.

An interesting way of revising what you have learnt is to use the index to look up all that the book tells you about important subjects, e.g. energy, men of science, sunlight, nerves.

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ANSWERS TO THE HUNDRED QUESTIONS

1. living.
2. plants.
3. breathe.
4. food.
5. air.
6. plants.
7. energy.
8. movements.
9. guided.
10. sensing.
11. seeing.
12. hearing.
13. nostrils (noses).
14. stomata.
15. gills.
16. more.
17. Carbon dioxide.
18. burns.
19. heavier.
20. extinguishes puts out).
21. need.
22. starch.
23. sugar.
24. fats.
25. Body-building.
26. salts.
27. vitamins.
28. soluble.
29. salts.
30. sunlight.
31. carbon dioxide.
32. starch.
33. water.
34. sugar.
35. soluble.
36. sap.
37. stored up.
38. sugar.
39. starch.
40. oil.
41. energy.
42. muscles.
43. contracting.
44. work.
45. force.
46. energy.
47. forces.
48. pull (force).
49. force of gravity.
50. centrifugal force.
51. friction.
52. bones.
53. fulcrum.
54. moment.
55. amount of the force.
56. distance from the fulcrum.
57. equal.
58. centre of gravity.
59. vertical.
60. outside (beyond).
61. mechanical.
62. third.
63. speed.
64. light.
65. retinas.
66. optic.
67. iris.
68. reflect.
69. absorb.
70. straight.
71. smooth.
72. transparent.
73. refracted (bent).
74. lens.
75. focuses.
76. convex.
77. concave.
78. silver.
79. vibrations.
80. ear-drums.
81. regular.
82. noise.
83. louder.
84. higher.
85. shortening.
86. thinner.
87. increasing.
88. 0·03.
89. 3·5.
90. At least 45 miles.
91. lime-water.
92. water vapour.
93. salts.
94. iodine solution.
95. foot-pound.
96. pupil.
97. about 186,000 miles per second.
98. about 93 million miles.
99. air.
100. about 1100 feet per second.

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